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THE CHEMISTRY OF ARTIFICIAL LIGHT.

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CHEMISTRY OF ARTIFICIAL LIGHT:

INCLUDING THE

HISTORY OF WAX, TALLOW, AND SPERM CANDLES, AND THE MANUFACTURE OF GAS,

THEIR VARIOUS ILLUMINATING POWERS COMPARED WITH ANIMAL AND VEGETABLE OILS,

AND

A DESCRIPTIVE SKETCH OF LAMPS AND OTHER APPARATUS.

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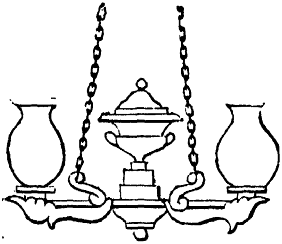

CHEMISTRY OF ARTIFICIAL ILLUMINATION.

Historical Notice.—The advantages of artificial light are so numerous and important, that they must have claimed attention from the very earliest period of history: in fact, long and long before man had commenced his work of civilization, the light of the cheerful fire must have been a source of comfort and security; for, perhaps, nothing assists so powerfully in dispelling the gloom of darkness, and banishing the terrors of night, as the lustre of a cheerful fire. And then, as civilization advanced, the usefulness of artificial light must have been perceived in a thousand ways. True, it might at first have been employed merely as a luxury among the rich, but in process of time it became a necessary even with the poor; and were we now to deprive man of all means of obtaining artificial light, the consequences would be terrible,—we should cripple his energies and impoverish his intellect,—the greater portion of his time would be lost to him,—every industrial occupation would be hindered,—the very safety of the community would be endangered,—and, in fact, the wealth and commerce of every nation would be seriously affected. These considerations endow our subject with an interest of no ordinary character; and we may truly say, that few inquiries would furnish so profitable a result as a complete history of Domestic Illumination, "tracing its gradual development from the solitary watch-lantern, graven on the pyramid, through the graceful but very imperfect lamps of the Greek and Roman period, as exhibited in our museums, and the clumsy contrivances of the middle ages, up to the productions of modern times, satisfying the demands both of taste and science. In such a narrative might be shown the progress of light, in the literal signification of the word, by a careful examination of the various forms in which it has been at different times employed,—as lamp, lantern, torch, flambeau, falot or cresset, candle, and gas,—whether for the celebration of religious ceremonies, for increasing domestic comfort, adding to the security of the streets, or forming a beacon to guide the mariner at night. It would be, at the same time, a history glancing at the advancement which the improvements in illumination have given to the social condition of mankind, and at the advantages which science has derived from the study of this subject." Besides which, there would be mixed up with such an historical account many of the fanciful hypotheses and highly-poetical conceits in respect of the nature of fire, which have at various times occupied the attention of man.

Perhaps the earliest source of artificial light was the wood-fire, blazing in the recesses of the forest, or in the hut of the savage; and then, as experience led to the discovery of the fact that different kinds of wood burn with different degrees of splendour, it must have been perceived that certain vegetable substances might be employed, in preference to others, as a means of obtaining light. In this way a splinter of pine, the resinous bark of a tree, or even the oily kernel of a nut, might early have been resorted to for such a purpose; indeed, we are told that the inhabitants of Tortuga had long used the wood of yellow sandal; those of New England made choice of a resinous splinter of pine; the natives of British Guiana selected the wood of an amyris; and in Otaheite, the candle was a row of nuts fastened upon a skewer. Again, accident must soon have taught mankind that the resinous exudations of trees, the fat of animals, and the bitumen and naphthas of the mineral kingdom, were not only highly combustible, but that, while burning, they were also highly luminous. Having learnt this fact, it required but little ingenuity to suggest the use of some porous material upon which the combustible might be smeared, or into which it might be dipped, before it was burnt. In this way the torch, the candle, and the lamp were doubtless invented.

The first authentic evidence that we have of the use of candles is furnished by Pliny in the 13th Book of his Natural History. He there says, in speaking of the lost books of Numa, that when Terentius the scribe discovered the sepulchre of the king, he found in it a parcel of books tied round in every way with *candles*, after the manner of the cere-cloth. This story is quoted from Piso, Tuditanus, Varro, Antias, and others: it is also repeated by Livy, who states that the candles were two in number. Now as Numa was the successor of Romulus, and reigned about 700 years before the birth of Christ, it is evident that candles were used in the earliest days of Roman history; judging, also, from the use to which they had been put, it would appear that they were composed of string or rope covered with some combustible, perhaps pitch or wax. It is to be regretted, however, that Pliny has not given us a more particular account of the construction of those candles; indeed, he has not informed us how any of the candles of his time were manufactured; he merely alludes to the subject incidentally. Thus, in his chapter on Willows, he says that the pith of the brittle rushes, which grow in marshy places, is used for making wicks for watch-candles and funeral-lights, to burn by a dead body while it lieth above the ground; and, in a subsequent chapter on Flax, he states that the part of the reed which is outermost and nearest to the peel, or rind, is called tow, and is good for nothing but to make lamp-match or candle-wick: nothing whatever being said respecting the material which was put about those wicks. The inference, however, is that the watch-candles in Pliny's time were like our rush-lights, and that the others were similar to the pitched rope which we employ, after the fashion of a torch, for common illuminating purpose. Fosbrooke informs us, in his Encyclopedia of Antiquities, that the candles of the ancients were sometimes made of the leaves of the papyrus covered with wax or tallow: and he remarks that common kitchen-stuff was used for such purposes as far back as the days of Augustine. A proof of this is to be found in the writings of Apuleius, who speaks of two kinds of candles—namely, the *cerei*, or wax, and the *lebacei*, or tallow.

During the middle ages wax was extensively employed for purposes of illumination; and, according to Fosbrooke, the candles were not made by regular craftsmen, but by the monks, and the servants of nobility. An illustration of this is to be found in Asser's Annals, where an account is given of the manner in which King Alfred directed his candles to be formed. "He commanded his chaplain to supply wax in sufficient quan-

tity; and he caused it to be weighed in such a manner, that when there was so much of it as would equal the weight of seventy-two pence, he caused the chaplain to make six candles thereof, each of equal length, so that each candle might have twelve divisions marked across it." These candles, when burnt in succession, lasted for twenty-four hours, and each division indicated the third of an hour.

Up to that time the use of candles was chiefly confined to the churches, the monasteries, and the houses of the nobility; but in the fifteenth century the employment of candles had become very general; and at that time the trade of making them had acquired so much importance, that the chandlers of London obtained an act of incorporation. The candles of those days were all made by dipping the wick into the melted wax or tallow; but in the eighteenth century, the Sieur de Brez of Paris invented the plan which is now practised, of casting them in metal moulds, and later still the wax candles were made by rolling the wax around the wick. All subsequent improvements in the manufacture of candles have resulted from the very elaborate investigations of Chevreul into the composition of fats; indeed, most of his results have been made the basis of the several patents of modern time, as, for example, those of Bolts, Fremy, De Milly, Gwynne, Wilson, and others.

Lamps are also contrivances of very ancient date. They are frequently mentioned in the sacred writings; and there can be no doubt that they were much better known and more generally used than candles. Clemens Alexandrinus and Eusebius ascribe their invention to the Egyptians; but it is rather a singular fact that they were not well known in Greece during the time of Homer—at least, he has not referred to them. In his story of Penelope, he says, as most classical scholars will remember, that the suitors of Penelope paid homage to her with torches and odoriferous wood laid in a brazier. Lamps, however, were common enough in Rome during the early period of her history. Pliny frequently refers to them, and even describes the oil and the wicks that were burnt in them. The cities of Herculaneum and Pompeii have furnished us with excellent examples of both the form and the material of ancient lamps. It would appear that at first they were made of baked clay (terra-cotta), and that the design was simple in the extreme—an oval or elongated vessel, having a lip at one end for the wick; but in process of time, as the habits of the Romans became more luxurious and expensive, the material was changed for gold, silver, or Corinthian brass, and the design became more complicated. These lamps were either suspended from the ceiling or arranged in rows on a stand or candelabrum, the designs of some of which are exceedingly beautiful. The light which they furnished must have been dim and unsteady, for the construction of the lamp was always the same—namely, a solid wick immersed in a vegetable oil. Pliny says that the inhabitants of Sicily burned a kind of bitumen, resembling an unctuous or oily liquor; and that they collected it from the surface of a spring in the territory of Agrigentum. In other cases the oil which they used was of vegetable origin—it was extracted from the fruits of castor or olive; and in more recent times animal fats were employed. This was the condition of things until a very modern period, when M. Argand of Geneva effected a complete change in the art of illumination. Every one is acquainted with the lamp that bears his name, the principle of which is, that the oil burns at a high temperature with a plentiful supply of atmospheric air. This is accomplished by means of a hollow cylindrical wick, and a glass chimney which surrounds the flame. Few improvements of any practical importance have been made on this principle, notwithstanding that many contrivances have been originated, and various combustible liquids resorted to.

The history of street-lighting furnishes many examples of the slow progress with which the art of domestic illumination has advanced. At first, the only lights in the public highways were those of the cautious citizen, who deemed it prudent to make his nocturnal visits under the protection of a link, a flambeau, or a lantern. We are told that the streets of Rome, even in her palmiest days, rarely exhibited more than one or two lanterns, which were suspended over the baths and places of public resort. Now and then they were illuminated for a festival, and sometimes the forum was lighted up for a midnight exhibition; but with these few exceptions, the city was a city of darkness. In the fourth century, the streets of Antioch and Edessa were furnished with public lamps. Libanius, in his panegyric of the former, says, "The light of the sun is succeeded by other lights, which are far superior to the lamps lighted by the Egyptians on the festival of Minerva of Sais. The night with us differs from the day, only in the appearance of the light: and with regard to labour and employment, everything goes on well; for some work continually, while others laugh and amuse themselves with singing." This fact is confirmed by Jerome, who tells us of a serious dispute that was maintained for some hours in the streets of Antioch, between a disciple of Lucifer and one of the orthodox: he says that the dispute was kept up until the streets were lighted, and then the disputants spat in each other's face and retired. In the history of Jesue Stylites, we are informed that Eulogius, the governor of Edessa in Syria, ordered lamps to be kept burning in the streets during the night; and that he employed for that purpose a part of the oil which was before given to the churches and monasteries.

It is worthy of notice, however, that public illuminations, either on account of religious festivals, or general rejoicings, were very common with the ancients, and are of great antiquity. Herodotus states that the Egyptians had a festival of much solemnity, during which lamps were placed before the houses, and kept burning throughout the night; the Jews, also, celebrated their *festum encœniorum* in like manner. According to Æschylus, it would appear that the Greeks had their nights of public rejoicing; and there can be no doubt that the Romans were continually in the habit of lighting up their streets with lamps and torches, whenever an event of public importance commanded their attention. In some instances, these displays were wholly unpremeditated, as when an orator distinguished himself in the senate, or a soldier in the camp. Cicero was thus honoured when he defeated the conspiracy of Cataline; and many a Roman general has been encouraged in his march by a like display of public enthusiasm.

Until very recently, the modern cities of Europe were no better provided for in this respect than the ancient. It is true that statutes were made, and orders proclaimed, to the effect that every citizen should contribute his share to a system of general illumination. This was effected by placing a candle in each of the lower windows of the house, and keeping it burning from night-fall to the hour of twelve. At first the performance of this duty was optional, but at last it became compulsory; nevertheless, it was at all times so sadly neglected, that the thief and the assassin had abundant opportunities for mischief. Paris was the first city to improve on this condition of things; for in the year 1558 huge contrivances, called *falots*, were erected in the principal thoroughfares. The *falot* was a sort of vase filled with pitch, resin, and such-like things, in a state of combustion; but it was soon found that this mode of lighting the streets was expensive, dangerous, and inconvenient, and consequently the falot was quickly displaced by the lantern, which was a rude frame covered with horn or varnished leather. For more than a hundred years this was the plan of illumination generally adopted; and, as may be

supposed, the light was too feeble for any useful purpose: indeed, no ci-
tance ventured abroad after dark without his torch or flambeau. The latter, therefore, became so indispensable to the midnight traveller, that an ingenious Italian, named Laudati, conceived the idea of opening stalls for their hire. He started his business in Paris in the month of March, 1662, and he managed it so well that he obtained the entire monopoly of the whole city; his charge for a link was from three to five sous the quarter of an hour, according to the rank of his customer. In 1667, Nicholas de Reynio, the first lieutenant-general of police, introduced a still better system of street-lighting. He invented lamps of glass, which from their resemblance to a bucket were called *lanternes a seau*. These he fixed in the middle of the streets exactly in the same way as they are now suspended in many parts of France, by means of ropes or wires fixed at each side of the street, the lamp being suspended in the centre.

We have no means of showing when London was first lighted with lamps; though Maitland says, in his "History of the Metropolis," that an order was issued as early as the year 1414, commanding the inhabitants to hang out lanterns for the benefit of passers-by. This information is derived from Stow, who in his "Survey of London" remarks, that "in 1417 Sir Henry Barton, the Mayor, ordained lanthorns with lights to be hanged out in the winter evenings, betwixt Hallontide and Candlemasse." It does not appear, however, that these orders were much attended to, for we find that they were repeated again and again over a period of three hundred years. At the expiration of that time the Corporation of London determined on removing the service altogether out of the hands of the inhabitants; they therefore entered into contract with a person to set up the public lights, and to attend properly to them—for which they gave him permission to charge six shillings a-year to every householder whose annual rent exceeded ten pounds. In 1736 the Lord Mayor and Common Council applied to parliament for power to light the streets in a better manner. This power was further increased in 1744; and from that time the illumination of the City has been gradually improving.

Most of the preceding facts have been derived from Beckmann, who tells us that the following are the dates when public lamps were introduced into the other cities of Europe:—Amsterdam, 1669; Hamburg, 1675; Copenhagen, 1681; Berlin, 1682; Hanover, 1696; Leipsic, 1702; Vienna, 1704; Dresden, 1705; Halle, 1728; Birmingham, 1783; Brunswick, 1765; Nantes and Versailles, 1777; Zurich, 1778; and Strasburg in the year following.

In very recent times the greatest of all improvements in street-lighting has been effected by the use of gas; and those who can remember the old-fashioned lamp, with its miserable glimmer, and the dangers which constantly beset the traveller after nightfall, will have no hesitation in saying that the employment of gas for illuminating purposes has been one of the most important events of modern time. In truth, it has not only been the means of effecting a wonderful change in the whole system of artificial illumination, but it has also produced an equally important change in the domestic concerns of the people: it has encouraged industry, developed the arts, protected property, diminished crime, and operated in a thousand ways as a medium of wealth, prosperity, and social improvement. All this has been accomplished in less than half a century for Mr. Clegg tells us in his work on gas-lighting that he himself, in 1813, was the first to put gas into the lamps of Westminster; and he has also given us a graphic account of the fear and wonder with which it was contemplated. Now, however, it is one of the most familiar objects of daily life; for there are almost as many gas-lights in this metropolis as there are human individuals. What would Beckmann say of all this, if

in the year 1786 he imagined the lighting of London to be perfect; and thought that the appearance of the City after dark, when seen from a distance, was noble and magnificent? Of a verity, his admiration would be boundless. One thing, however, is still wanted to make gas the greatest boon of the nineteenth century—that is, a guarantee in respect of its purity and harmless qualities. Already the demand for these has become urgent; and it will not be long before the gas companies of England will find it to their advantage to yield to it. In fact, the City of London has, as usual, taken the initiative in this matter, and has appointed an officer to test the quality of the gas supplied within its boundaries. The results are so important to the community, that all other cities and towns will ere long follow the example; and then we shall hope to see the art of domestic illumination made more perfect than it is at present.

ON COMBUSTION AND FLAME.

General Remarks.—Artificial light is due in almost every instance to chemical action—that is, to a rapid or energetic union of two or more substances, and the formation of new compounds. At one time it was thought that matter in the act of burning was destroyed, and thus the term combustion was used to designate the phenomena: but we now know that matter is indestructible, and that substances while burning merely change their form. In proof of this, it may be mentioned that the chemist is enabled to ascertain the exact composition of an organic substance, by simply collecting and weighing the products of its combustion. This, indeed, constitutes the principle of every organic analysis.

Those substances which evolve light and heat during their chemical union, are generally distinguished by the terms combustible and supporter,—the former term being applied to the body which burns, and the latter to that which permits of the burning. We speak, for example, of wood, tallow, and coal as combustibles, and of atmospheric air, oxygen, and chlorine as supporters; but a very little reflection will show that those expressions are altogether arbitrary, and that they might in most cases be reversed without destroying their sense. This will be clear from what follows. When coal-gas is burnt in atmospheric air or oxygen, we call the gas the combustible, and the air or oxygen the supporter; but by changing this condition of things, and igniting a jet of air in a vessel of coal-gas, we should then call the air the combustible and the gas the supporter; from which it must be evident that the phenomena of combustion are due to a reciprocal play of affinities, in which one element takes as large a share as the other; and that the distinction of property, as implied by the terms combustible and supporter, is not founded on fact: nevertheless, we still continue to make use of those terms, because of the convenience they afford in description.

Theories of Combustion.—For a long time the phenomena of combustion were thought to be dependent on the evolution of a peculiar subtle principle called *phlogiston*. This hypothesis was originated by Becher in the seventeenth century, but it was not elaborated until the days of Stahl, when it was universally accepted among chemists as the Phlogistic theory. For more than a hundred years the theory held a prominent place in the science of chemistry; and although it was founded in error, or rather in a total misapprehension of facts, yet its truthfulness was not doubted until the time of Lavoisier, when by an accurate examination of the facts he exposed its fallacy. According to the Stahlian theory, there was something—namely, phlogiston—always given out during

combustion, from which it might reasonably be inferred that the body became lighter; but by collecting the burnt products and weighing them, Lavoisier showed that it actually became heavier, and that something must, therefore, have been absorbed or taken in. This something he soon found was derived from the atmosphere, and was the gas just then discovered by Scheele and Priestley. Having determined these facts, and tested their truthfulness in every possible manner, he boldly advanced his new theory of combustion, the Antiphlogistic; in which he said that the phenomena of combustion were *at all times* due to the rapid chemical union of oxygen with a combustible. Had Lavoisier been content to say that the phenomena were *usually* dependent on such a combination, it is probable that the theory would have existed in a modified form until the present time; but in his attempts to make it too general in its application, he effected its ruin: for in the course of a few years the investigations of Sir Humphry Davy into the properties and elementary nature of chlorine gas, demonstrated the fact, that combustion might be effected without the aid of oxygen at all. This was proved by the action of chlorine on antimony or copper; and from that time the phlogistic theories were put aside; and chemists have ever since regarded the phenomena in question, not as the result of any particular kind of combination, but merely as the energetic display of ordinary chemical action. And here we may remark, that there is not, perhaps, in the whole range of chemical science a subject that offers so many interesting facts for contemplation, as that to which we have just alluded; for it teaches us that the progress of human knowledge is often dependent, not so much on the discovery of great and important truths, as on the manner in which they are contemplated; and if men's minds are not prepared for the reception of those truths, they will either be disregarded, or else made the means of propagating error. This was the case with the theory of Becher and Stahl, which had the effect of distorting every fact that came under its influence. In this way for years it delayed the progress of science, and checked the development of truth. History tells us that for more than a century before the discoveries of Lavoisier, the main facts of his investigations were broadly set forth in the writings of Hooke and Mayew; but from the circumstance that those facts were premature—that men's minds were not prepared to receive them, and that chemists were infatuated and led astray by the false doctrines of Becher and Stahl—the more humble but important truths of Hooke and Mayew were allowed to pass unnoticed; and they lay dormant for more than a hundred years.

Manner in which Combustion may go on.—An examination of this question will show that most substances have the power of burning in three ways; namely, by slow oxydation, when little or no light is evolved; by a more rapid combination, when the burning becomes so hot as to render itself luminous; and by a still more energetic action when it bursts into flame. We have examples of the first of these processes in the phenomena termed *Eremacausis*, or slow burning, as is witnessed in the glowing of phosphorus, and in the luminosity of decaying wood or putrifying fish. In most of these cases, the heat and light evolved at any given moment are not very considerable; and few persons would be disposed to regard the phenomena as those of combustion; but when it becomes known that the total amount of heat, and perhaps also of light, generated during this slow kind of oxydation is exactly the same as that evolved during the most rapid combustion of the same substances, there will be no difficulty in understanding that the phenomena in the two cases are referable to the same kind of chemical action, and belong to the same category.

The second mode of combustion is observed when coal-gas, or the vapour of ether, alcohol, or wood-spirit, is mixed with air, and brought under the influence of spongy

platinum or fine platinum wire. This is best effected by suspending a coil of the wire in the flame of either of the combustibles, then blowing the flame out, and allowing the vapour or gas to play on the surface of the metal: in this way the platinum will keep up the combustion, and will continue to glow, although the vapour or gas will not be inflamed.

The third kind of combustion is produced whenever a sufficiently high temperature is applied to any kind of vaporous matter so as to inflame it. The temperature at which this is effected varies with different combustibles; some take fire at ordinary temperatures, as finely-divided phosphorus, and phosphuretted hydrogen; whereas, solid or massive phosphorus requires a temperature of 140° to inflame it; sulphur takes fire at about 500°; hydrogen and carbonic oxide at 1000° (which is a red-heat); and coal-gas, ether, turpentine, alcohol, oil, tallow, and wood, at about 2000° (or an incipient white-heat); but when once inflamed, they all continue to burn at a very exalted temperature.

The Nature of Flame.—The preceding remarks will be sufficient to show that flame is nothing more than gaseous matter burning at a very high temperature. We may prove this by experiment. If we take a coil of iron-wire, or a piece of watch-spring, and arm it at one end with a fragment of burning wood, then introduce it into a jar of oxygen gas, the metal will take fire and burn with the most brilliant scintillations, but it will not produce flame. Again, if we expose wood to the action of heat in a closed vessel, so as to drive off all volatile matters and obtain its fixed solid constituent, charcoal, we may burn it in an atmosphere of oxygen without producing flame. In both of these examples, the absence of flame is entirely due to the absence of gaseous matter in the combustibles; and to show that a high temperature is necessary to produce flame, we have only to burn coal-gas, alcohol, ether, or wood-spirit at the low temperature of glowing platinum, and they will not inflame.

It may be thought, perhaps, that in the case of wood, tallow, oil, phosphorus &c., the flame cannot result from gaseous matter, because those bodies are either solid or liquid in their nature; but a little consideration will teach us that in the act of burning they all become converted into gases or vapours. This may be easily demonstrated in the case of a common candle or oil-lamp, the wick of which conveys the fluid combustible to the flame, where it is decomposed and converted into vapour. Now if we hold a small glass tube, or even a piece of tobacco-pipe, in the flame of the candle, so that the end of the tube shall be exactly over, and almost in contact with, the top of the wick, it will collect the combustible vapour and convey it out of the flame, whence it may be burnt by applying a light to the opposite end of the tube (Fig. 1). This experiment also proves that flame is hollow: it consists, in fact, of three cones placed one over the other. The inner cone, which is of a dark colour, and surrounds the wick, is formed by the vapour of the decomposed tallow. The second cone is the luminous one; it envelops the preceding on all sides, and consists of the ignited particles of the gas making its way outwards to the air. The third or outermost cone is nearly invisible; it constitutes that pale blue film which everywhere surrounds the luminous part of the flame. We may make this cone more evident by bringing a piece of thread moistened with salt into the lower edge of the flame, when the cone will be instantly lighted up with a deep yellow tinge. Another mode of discovering it is to screen off the luminous cone by means of the hand; or it may be rendered visible by intersecting the flame with a piece of fine

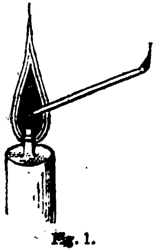

Fig. 1.

platinum wire, or wire gauze, the ignition of which discovers the exact boundary of the cone. This cone is made up of gas in an actual state of combustion; for it is here, and here only, that the process of oxydation is rapidly going on.

Cause of Light in Flame.—A little experience will inform us that different combustible substances burn with different degrees of intensity (Fig. 2). We will endeavour to show that this is wholly dependent on the number of solid particles that are ignited within the flame. If we take a jet of nitrogen gas and fire it, or make use of a flame of alcohol from a common spirit-lamp, we shall notice that neither of these bodies burn with any great amount of light; the case is very different, however, with a candle, or even with a jet of coal-gas. Now, in the former examples the hydrogen and the spirit do not contain any solid particles, and consequently do not contain any species of matter that can, by its ignition, evolve light; but in the latter examples the case is very different—for by intersecting the flame with a cold plate, we shall find that there are myriads of solid particles in the form of soot, which by their ignition produce that intensity of light for which such combustibles are valued. Again, when sulphur is burnt in oxygen gas it evolves a faint blue spectral light, that is hardly sufficient to illuminate the dial of a watch; but when phosphorus is treated in this manner, it emits a volume of light that rivals the intensity of the sun. It will be noticed that the products of the former are wanting in solid particles, whereas those of the latter are made up of myriads of white flakes of solid phosphoric acid. It is on this account that carbonic oxide and wood-spirit, as well as hydrogen, sulphur, and alcohol, burn with little or no light; while zinc, antimony, ether, turpentine, oil, tallow, and coal-gas, burn with more or less splendour. But we may communicate a great degree of brilliancy to some of the former by giving them a large proportion of solid particles; for example, when we sift a little magnesia into a jet of hydrogen, its illuminating power is at once raised to a high standard; and the same thing happens if we employ lime, oxide of zinc, or white antimony, instead of the magnesia. So also if we naphthalize the gas by passing it through a chamber containing ether, turpentine, benzole, or coal naphtha, its light is increased to that of the best description of coal-gas. In fact, coal-gas consists, in great part, of hydrogen and carburetted hydrogen, both of which are, as it were, naphthalized with other compounds that give it illuminating power. But the most striking example that we can refer to in illustration of the fact that the light of flame is dependent on the presence of solid particles, is afforded by the results obtained with the oxy-hydrogen blowpipe. When the flame of the mixed oxygen and hydrogen gases is seen as it issues from the jet without impinging on any solid substance, it strikes the observer as being an insignificant and almost invisible object; but directly it is thrown on a piece of lime or other material that will give it solid particles, it instantly becomes one of the most splendid lights with which we are acquainted: in fact, the intensity of the oxy-hydrogen light is so great, that when its rays are reflected by means of a concave mirror, they are distinctly visible at a distance of sixty-eight miles. We can easily understand,

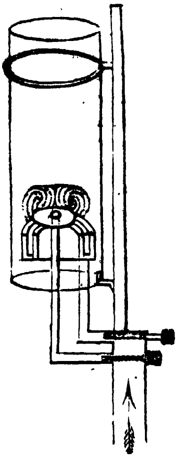

Fig. 2.

therefore, why it was so earnestly proposed by Lieutenant Drummond as a means of illuminating light-houses. So, again, with the electric light, the brilliancy of which is dependent on a number of minute particles of charcoal that are intensely heated by the galvanic current. The splendour of this light is scarcely inferior to that of the sun, for on one occasion when it was tested, it was found to be equal to that of 300,000 wax candles, and was distinctly seen at a distance of several miles.

Lastly, it may be stated, as the converse of the preceding, that we can always reduce the illuminating power of flame by diminishing the amount of solid material contained in it. To take coal-gas by way of example, we shall find that the light may be kept down, or even destroyed altogether, by blowing atmospheric air into it. This sometimes happens with the lights in the streets, and then the flame is reduced to an insignificant blue flicker. The same thing occurs if we mix atmospheric air with the gas before it is consumed, or if we employ a glass chimney that is too tall for the size of the flame. In all these instances, the solid particles of charcoal contained in the gas are burnt too speedily, and consequently there is no time for their previous ignition. This teaches us that there is one great point always to be attended to in the management of gas for illuminating purposes: we should take care that the supply of atmospheric air is so regulated that, on the one hand, the solid particles shall not be instantly consumed; and on the other, that they shall not escape as uncombined soot. Many gas-burners are constructed so as to effect this of themselves; this is the case with the fish-tail and the bat's-wing, both of which present a thin stratum of flame for the action of atmospheric oxygen. Other burners, as the Argand and its modifications, require a glass or chimney for the purpose of effecting a proper supply of air. The chimney acts by creating a draught, and so causing the air to play into the body of the flame; but if the chimney be too high, the draught will be too great, and the gas will be overburnt; whereas, if it be too low, the current of air will not be sufficiently strong, and the carbon of the gas will escape in the form of soot or smoke. As a rule, the flame should be kept at about one inch below the top of the chimney. Mr. Billow, of London, has contrived a burner, which not only demonstrates the nature of flame and the cause of its light, but also shows the effects of an under supply of atmospheric air. In ordinary burners the air is admitted to the flame on all sides, and it even passes up into its interior; but in the burner contrived by Mr. Billow the inner supply of atmospheric air is cut off, and consequently the gas is but imperfectly consumed. The result of this is that carbon is liberated, and, by the construction of the burner, it is made to girate round and round, until it collects into little solid masses, which fall by reason of their own weight; directly this happens they come into contact with a part of the flame where combustion is actively going on, and they are instantly projected into the atmosphere like so many diminutive rockets. Our readers will find a description of this burner at page 357 of the second volume of the Journal of Gas-lighting.

Quantity and Intensity of Flame.—It must have been noticed again and again by those who are in the habit of pursuing their avocations by the aid of artificial light, that there is a great difference in the practical value of different kinds of illuminating agents; for example, the eye is often most painfully excited with the strong glare of certainvarieties of light, although there is not enough of it to produce the necessary illumination of surrounding objects; on the other hand, we sometimes perceive that the light is particularly inoffensive, notwithstanding that everything about us is brightly and sufficiently illuminated. It is probable that these two conditions are entirely dependent on two states of light, which have not yet been properly appreciated. To the

one we apply the term *intensity*, and to the other *quantity*. We have examples of the former in the electric-light, in the Drummond light, and in the vivid combustion which is going on in the burners of Leslie and Wingfield; of the latter in the diffused light of day, and in the illumination that is produced by a number of separated gas jets. In the one case we have comparatively few solid particles, but they are heated to a high degree of intensity; in the other we have a much larger number of ignited points, but their ignition is not carried to so high a temperature. These facts have not yet received so much attention as they deserve; and in all our endeavours to improve the quality of a burner, we should never lose sight of the fact that the human eye requires far more of quantity than it does of intensity for agreeable vision.

The Colour of Flame.—Our preceding remarks have gone to show that the light of flame is dependent on the *number* of solid particles present in it; we will now demonstrate that the colour of the light is dependent on the *nature* of those particles. The flame of alcohol or wood-spirit is naturally colourless; but we may give it various tints by saturating the spirit with different kinds of saline substances. Chloride of potassium will make it violet; boracic acid or chloride of barium, green; chloride of copper, blue; common salt, yellow; chloride of strontium, red; and chloride of lithium makes it of a carmine tint. The same substances produce a similar effect when they are sifted into the flame of hydrogen; and the pyrotechnist relies upon these properties in producing the various coloured devises which are the glory of his art. Some years ago there was an exhibition in London of philosophical fire-works; and it was described at the time as a very great novelty. It was said to be effected by the combustion of gases charged with various substances, and ignited from jets arranged in different forms, as spirals, wheels, stars, &c., the tints being chiefly red, blue, green, and purple. It is not known what were the materials used; but from the strong smell of ether and spirit in the room, there is no doubt that these liquids were among the constituents of the gases, and that they were employed as the solvents of different saline compounds: in fact, the chromatic cloud which used to attract so much attention a few years since was nothing more than the burning vapour of spirit charged with the preceding salts.

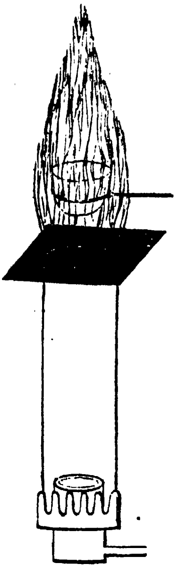

Fig. 3.

The Heat of Flame.—Under ordinary circumstances the combustion of gaseous matter takes place only at the exterior of a flame—that is, where the surface of the luminous cone is in immediate contact with the atmosphere; but we may increase these points of contact, and therefore the combustion and heat, by throwing air into the interior of the flame, or by mixing the combustible with the atmosphere before it is burnt. In this way we can increase the heat of flame to almost any extent; indeed, the principle of the common blowpipe, of which there are numerous varieties, is founded on this fact; and if we blow a jet of oxygen into a flame of coal-gas by means of a double tube, we obtain a temperature that is sufficiently high to melt platinum. A mixture of air and coal-

gas may also be burnt over a chimney covered with wire-gauze, and then the heat produced is sufficient to keep a small crucible at a bright red heat (Fig. 3); but the highest temperature of all is generated by the combustion of a mixture of two parts, by measure, of hydrogen gas and one of oxygen. This constitutes the mixture of the oxy-hydrogen blowpipe, which has been so useful an instrument in the hands of the chemist. Different combustible substances do not, however, produce the same amount of heat, or consume the same relative proportion of oxygen. This is an important fact, and it should always be remembered in considering the effect produced by different illuminating agents in the atmosphere of the room in which they are burnt. The following table exhibits, in approximate numbers, the relative values of different combustibles in this respect:—

Name of Combustible.	Weight of Water raised 1° by 1 of body.	Weight of Oxygen consumed by 1 of body.	Weight of Carbonic Acid produced by 1 of body.
Carbonic oxide	3650	0·57	1·57
Cyanogen gas	9380	1·23	1·70
Olefiant gas..........	21630	3·41	3·14
Marsh gas	23610	4·00	2·75
Hydrogen gas........	61230	8·00	0·00
Wood-spirit..........	9930	1·50	1·37
Alcohol	12630	2·09	1·87
Rape oil	16770	2·89	2·81
Sperm oil............	16950	2·90	2·82
Olive oil	17130	2·90	2·82
Turpentine	19110	3·29	3·27
Tallow..............	14430	2·90	2·91
Wax................	16230	3·00	2·92
Spermaceti	17130	3·10	3·00
Sulphur	4530	1·00	
Phosphorus	10830	1·25	

Coal-gas is chiefly composed of hydrogen and light carburetted hydrogen, with which there is a small proportion of olefiant gas; it therefore evolves enough heat to raise about forty thousand times its weight of water one degree, and it produces about twice its weight of carbonic acid.

In order to show the advantage of well-purified coal-gas over all other materials for artificial illumination, as regards the injury done to the atmosphere of the room in which their combustion is going on, Dr. Frankland has given the following table, which exhibits the amount of carbonic acid produced by a number of illuminating agents, burnt in such quantity as to give a light for ten hours equal to that of twenty sperm candles, each consuming 120 grains per hour:—

Tallow	10·1 cubic feet.	London cannel-gas	3·0 cubic feet.
Wax	8·3 „	Hydro-carbon gas with Boghead coal-gas	2·6 „
Spermaceti	8·3 „	Hydro-carbon gas with Lesmahago coal-gas	2·3 „
Sperm oil	6·4 „		
Common London gas	5·0 „		
Manchester gas	4·0 „		

The Products of Combustion.—One of these—namely, carbonic acid—has been noticed in the preceding table; the other product of combustion is water. Occasionally there is also produced a small quantity of sulphurous acid; but, as a rule, it will be found that combustible substances are composed of only carbon, hydrogen, and oxygen. Coal-gas, however, contains a small proportion of bisulphuret of carbon, and sometimes a very perceptible quantity of sulphuretted hydrogen, both of which in burning produce sulphurous acid—the acid of the burning match; and this, by further oxydation of the air, becomes sulphuric acid, or oil of vitriol, a product which has been found to exert the most destructive influence on textile fabrics, as the covers of books, &c. Again, when coal-gas is not perfectly consumed, it generates aldehyde, volatile oil, and a few other compounds which are exceedingly offensive. This is experienced in every kind of gas-stove, where the flame is allowed to play on a large cooling or radiating surface; and hence it is advisable that gas should always be burnt in such a manner that the products of combustion may easily escape into the external atmosphere. Other illuminating agents, as tallow, oil, turpentine, &c., likewise give rise to the formation of unpleasant compounds when they are burnt at a low temperature. Every one must be acquainted with the odour of a smouldering candle or a badly-trimmed lamp; and when alcohol, or ether, or wood-spirit are burnt at the temperature of glowing platinum, they produce a number of most irritating compounds, as aldehyde, acetic acid, formic acid, &c. This teaches us that combustion should at all times be kept up with as much energy as is compatible with the required effect, and that the products of its action should be disposed of as speedily as possible.

Effect of Cooling Influences on Flame.—Every circumstance that tends to lower the temperature of flame, operates to a like extent in diminishing the intensity of its light. We see this when a large snuff collects on the wick of a tallow-candle—the carbon of which radiates the heat so fast, that the light and temperature of the flame are considerably reduced; and by bringing a mass of metal in contact with a small flame, the latter is immediately extinguished. Sir Humphry Davy was the first to investigate facts of this description; and he showed by his masterly researches that flame cannot exist below a certain temperature. This is easily proved by intersecting the flame of a candle with a piece of wire-gauze, having about thirty or forty meshes to the inch; or by endeavouring to pass the flame through a ring of stout copper-wire, or through a small hole punched in a sheet of that metal. In all these cases the flame will be extinguised above that point where the metal intersects it; and, although the inflammable vapour will continue to pass through the holes in the form of smoke, yet the cooling influence of the metal is so great, that the combustible gases will not be inflamed. The same process occurs when we place a layer of wire-gauze over the glass or chimney of an ordinary gas-burner; the wire will by its conducting power so far reduce the temperature of the flame, that it will not pass through to the apertures of the burner. Sir Humphry Davy took advantage of this important fact, and applied it in the construction of the safety-lamp, which has been of such essential service to the miner. "The Davy," as it is termed, is nothing more than a common oil-lamp, with a

cylinder or cage of wire-gauze surrounding the flame (Fig. 4). This gauze permits the passage of light, but it will not allow the flame to traverse it; and hence, it may be exposed to the most inflammable mixtures without danger of explosion. The miner knows when the atmosphere of the mine is explosive, by the enlargement of the flame and the burning of the fire-damp within the cylinder of wire-gauze, and he perceives a struggle, as it were, of the flame to pass out; but such a result is not possible, unless the cooling influence of the wire is prevented by its becoming almost red-hot. In this case there is danger; and the fire-damp of the mine may be exploded. These lamps are also employed in spirit warehouses, gas manufactories, in the sewers, and in all other localities where there is risk from explosion. The same principle was employed by Mr. Hemming in the manufacture of his safety jets for the oxy-hydrogen blowpipe. We have already said that the mixed gases which are used in this apparatus are exceedingly explosive; and if some contrivance were not adopted to prevent the backing of the flame, they would assuredly take fire. In fact, in the earlier experiments with the oxy-hydrogen blowpipe, this was a result of frequent occurrence; and Mr. Clarke tells us in his work on the subject, that he often narrowly escaped being killed by the bursting of his apparatus. On one occasion, when he was experimenting in the presence of some friends, "the reservoir for the compression of the gases, although made of thick copper, was torn in pieces; and the fragments flew with the force of cannon-shot in all directions, like the bursting of a bomb." To guard against the danger of such terrible consequences it was found necessary to protect the operator by means of a thick oaken screen. Mr. Hemming saw the disadvantage of all this; and adopting the facts that Sir Humphry Davy had recently brought to light, he contrived a safety jet that enabled the operator to do away with all the paraphernalia that had hitherto protected his life. His jet consists of a tube of brass, about six inches long and three-quarters of an inch in diameter, packed full of fine copper or brass wire: the wire is cut into lengths of six inches, then packed as close as possible in the tube, and finally wedged together by means of a central bar of metal. In this way a number of fine apertures are left for the passage of the gas; and the conducting or cooling power of the wire is so great, that the flame cannot pass back to the reservoir of mixed gases.

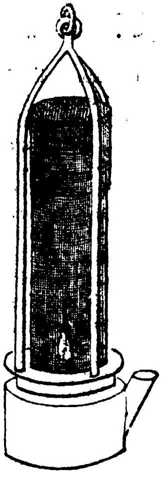

Fig. 4.

Another circumstance that operates in reducing the light and heat of flame is its rarefaction. When a flame is put under the exhausted receiver of an air-pump, it first enlarges, then the light diminishes, and finally it is extinguished. A flame of alcohol, ether, wood-spirit, wax, tallow, oil, or spermaceti, is extinguished when the rarefaction is carried to a fifth or sixth degree; hydrogen is extinguished when it is carried to a seventh or eighth degree; sulphur when it reaches the eighteenth degree; and phosphorus when it arrives at the thirtieth degree. "Slow combustion on the surface of platinum is exhibited by marsh-gas, down to a fourfold rarefaction of the air; by carbonic oxide to sixfold; by vapour of alcohol, ether, or wax, to eightfold; by olefiant gas, to ten or elevenfold; by hydrogen gas, to thirteenfold: and by vapour of sulphur, down to a twentyfold rarefaction of the air."—(Gmelin). From this it would follow that the

light emitted by any illuminating agent is not so great at the top of a mountain as at its base, or in the tropics as at the poles of the earth.

Lastly, it should be mentioned that the supply of very cold air to a flame always diminishes its light by the abstraction of heat; and hence we may improve the illuminating power of any combustible substance by supplying it with atmospheric air that has been previously warmed. The Rev. Mr. Bowditch, of Wakefield, has contrived an apparatus whereby this may be effected in the case of common gas. He places a disc of metal or a cup of glass, having a hole in its centre, on to the screw which receives the burner. This disc or cup is made the means of supporting an outer glass, and thus of directing the air down over the surface of the hot chimney before it enters the flame from below (Fig. 5). It is stated that the light is increased about 25 per cent. by this arrangement.

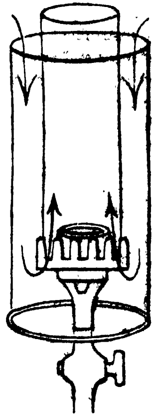

Fig. 5.

ON THE LAWS OF LIGHT AND RADIANT HEAT.

General Remarks.—We know nothing of the ultimate nature of light and heat, any more than we do of the nature of gravitation: indeed, there is no necessity for such knowledge; for, as in the case of the latter, all the phenomena may be thoroughly investigated, and their application satisfactorily made, without the slightest reference whatever to the abstract question of their ultimate cause. The only philosophical definition that can be given of these agents is, that they are the cause of certain phenomena, of which the sensations of vision and warmth are the most important. The laws which govern their manifestation are, in the two cases, almost identical; for the rays of both are propagated in straight lines, and traverse space with great velocity; they are also reflected, refracted, absorbed, dispersed, and polarized in exactly the same manner. We may here remark, that when the rays of light and heat impinge on any surface, they are disposed of in one or more of several ways: they may bound off or be reflected. They may pass through the body and undergo refraction or double refraction; they may be polarized, dispersed, or broken up into other rays; and they may also be absorbed or smothered.

Intensity of Light and Heat.—We know that the power of light and heat diminishes as we recede from any object that produces it, and the decrease is in proportion to the square of the distance; for example, if we have a certain amount of light; at a foot from its source, the intensity will be one-fourth at two feet, because the square of two is four; one-ninth at three feet ($3 \times 3 = 9$), one-sixteenth at four feet ($4 \times 4 = 16$), one twenty-fifth at five feet ($5 \times 5 = 25$), and so on. Upon this law, as it is termed, is founded all the methods now employed for estimating the relative value of different illuminating agents. The practice is called *Photometry*, and there are various modes of conducting it. Count Rumford adopted the plan of adjusting the lights at such a distance from an upright rod, that the shadows produced by each on a white screen should be equal; he then measured the distance of each light from the rod, and on squaring the number of inches he obtained two sets of figures which represented the relative values of the lights: by dividing the larger sum by the smaller, we obtain a product that expresses the fact in simpler terms. The late Mr. Ritchie contrived an apparatus

that consisted of two pieces of glass, placed at a right angle to each other, and so disposed, that the light from two opposite sources should be reflected upwards upon a piece of tissue-paper that covered two holes in a darkened chamber. When he had adjusted the instrument so as to obtain two reflections of equal intensity, he then measured the distances and proceeded as before. Leslie and Wheatstone have also invented photometers, which are useful enough for certain purposes; but they have all given place to the very simple contrivance of Professor Bunsen. It will be noticed that if a piece of white filtering-paper is painted over with melted wax or spermaceti, it acquires a greasy appearance and becomes translucent: if this be done so as to leave a spot or disc, about the size of a shilling, untouched in the centre of the paper, we shall find that the apparatus will have the following properties:—When examined by reflected light—that is, with the light on the same side of the paper as the observer is—the disc will look white and the surrounding greasy part dark; but by altering this condition of things, and looking at the paper by transmitted light—that is, with the light on the opposite side of the instrument—the disc will appear dark, and the surrounding greasy portion light and translucent. Lastly, if two lights of equal intensity are placed, one on each side of the paper, the disc will disappear entirely; for then the light of one side neutralises that of the other, and there is no disposition to produce either effect. Upon this is founded the principle of Bunsen's photometer. The instrument consists of a graduated rod about five feet in length, having a support at each end. The prepared paper is held by a frame which slides upon the rod between the lights. This frame is usually enclosed in a darkened chamber, so as to exclude all light but that emanating from the object to be tested. The frame containing the paper is slid to one side or the other until the disc entirely disappears, and thus we read off the relative values of two lights. In making experiments on coal-gas, it is usual to burn it at the rate of five cubic feet an hour, from an Argand burner having fifteen holes and a seven-inch chimney. The candle, which is used as a standard for comparison, is generally of sperm, and the rate of consumption is fixed at 120 grains per hour. When it happens that the consumption is greater than this, it may be reduced to the normal standard by a very simple calculation; thus—suppose that on experiment it was found that the light of the gas was equal to eleven candles of 140 grains' consumption; then as 120 grains is to 140, so is 11 candles to the standard value—namely, 12·8 candles.

In this way the following results have been obtained; and, in order that an estimate might be made of the relative values of different illuminating agents in respect of their consumption and heating power, other results have been appended:—

	Consumption of each candle or burner per hour.	Number required to produce the same light.	Total consumption per hour.	Illuminating power in standard candles.	Heating power in lbs. of water raised 1°.
Cannel coal-gas . . .	3·5 cub. ft.	2 burners	7 cub. ft.	28	4550
Common „ . . .	5 „ „	„ „	10 „ „	„	6500
Sperm oil in Argand . .	450 grs.	5 lamps	2250 grs.	„	5448
Sperm candles, 6 to lb. .	134 „	25 candles	3350 „	„	8223
Wax „ „ .	167 „	23 „	3841 „	„	8904
Cocoa-nut „ .	143 „	26 „	3718 „	„	8664
British sperm „ .	140 „	29 „	4060 „	„	8743
Composition „ .	144 „	30 „	4320 „	„	8906
Oil in common lamp .	133 „	36 lamps	4788 „	„	11595
Tallow moulds, 6 to lb. .	143 „	40 candles	5720 „	„	11793

The amount of heat, in these cases, has been determined by burning the lamp, or candle, under a vessel containing a given quantity of water, or in a space surrounded by a certain amount of that liquid, at a known temperature: from which it will be evident that, for the same amount of light, cannel-gas produces the least heat; then follows sperm oil in an Argand or carcel-lamp; then common coal-gas; then wax, sperm, and other candles; and, finally, oil in a common lamp, and tallow candles—both of which produce an enormous amount of heat in proportion to the light evolved.

Reflection.—When a beam of light or a ray of heat falls on a polished surface, a large portion of it bounds off or is reflected; and it will be found that the angle at which it bounds off is precisely the same as that at which it falls upon the surface. This fact is expressed in the law of reflection,—namely, that the angles of incidence and of reflection are equal. This law holds good under all circumstances, whether the angle be acute or obtuse, and whether the surface be plane or curved. The instruments that are used to reflect light or heat are called mirrors, specula, or reflectors; and they are commonly made either of polished metal or of glass silvered on one side. Their surfaces are either plane, concave, or convex; each of which produces its own particular effect. Plane mirrors do not alter the direction of the rays, but simply throw them off in the same manner as they receive them; in consequence of which they always produce an exact image of the object, both in respect of form and size; and the image invariably appears as if it were situated as far behind the mirror, as the object in front of it. The convex mirror has the effect of scattering or diverging the rays, and the peculiarity of its action is to produce an image of small size, and, as it were, at a great distance. The reverse is the case with the concave mirror; and hence this form is employed for magnifying objects, or for throwing the rays of light, or heat, to a great distance: for when it happens that parallel rays fall upon a concave mirror, they are brought to a point, or focus; while divergent rays, as from a lamp or candle, are made parallel. Mirrors of this description are, therefore, used in light-houses, because their effect is, to collect the rays from the lamp, and to throw them off in nearly a parallel direction, to a great distance.

Instruments for reflecting light have been employed from a very remote period. We learn from the 38th chapter of Exodus that the Egyptians used mirrors of brass; and Pliny informs us that the mirrors of his time were made of polished silver. Many persons are of opinion that Archimedes, two hundred and twelve years before Christ, employed mirrors for the purpose of focussing the sun's rays; and that by means of a combination of such instruments he set fire to the fleet of Marcellus, as it lay before the walls of Syracuse. To test the probability of this opinion, Father Kircher and his pupil Schotus visited that city, and made many experiments; the results of which were, that Archimedes could easily have performed such an exploit by the aid of a number of mirrors. Indeed, Buffon was so convinced of its practicability, that he went to the expense of having three hundred and sixty plane mirrors erected in a frame in such a manner that they all threw the sun's rays upon one spot. By means of this instrument he was enabled to melt pumice-stone at a distance of forty feet, and to kindle wood at a distance of two hundred and ten feet. Beckmann informs us that in the middle ages mirrors of steel were commonly used, and that in the thirteenth century they began to use mirrors of glass.

Transparency and Translucency.—These terms are applied to designate the property which certain substances possess of allowing the rays of light and heat to pass through them; and while on the one hand it may be stated that nearly everything in

nature is in certain states of tenuity more or less transparent and transcalent, so on the other hand it may be said that nothing is perfectly so. Even in the case of the diamond, of pure water, and of atmospheric air, all of which appear to be so exceedingly pellucid, a large portion of light and heat are always destroyed in thus passing through them, and we lose a considerable amount of light by placing glass globes over the flames of oil or gas.

Melloni has devoted much attention to the subject of the transmission of heat through different media; and the results of his investigations are to the effect that there are no direct relations between the transparency of a body and its power of transmitting heat. In fact, many substances, as blackened glass and black mica, will not allow light to traverse them at all, although they freely admit the passage of heat; and, on the other hand, many transparent bodies, as alum and sulphate of copper, are not at all transcalent. If 100 rays of heat fall on colourless glass, only 40 are transmitted, while yellow glass stops 78 per cent.; blue glass, 79; and deep violet only 66. Rock-salt is the most transcalent body known; it allows 92 per cent. of the heat of a lamp to pass through it; rock crystal, 38; white agate, 23; borax, 18; Rochelle salt, 11; amber, 11; alum, 9; white sugar-candy, 8; ice, 6; and sulphate of copper, 0. Among liquids he found that turpentine transmitted 31 per cent.; ether, 21; oil of vitriol, 17; and water, 11. These facts admit of many practical applications, especially in those cases where we wish to preserve the light but not the heat. In the oxy-hydrogen microscope, for example, a film of sulphate of copper is sometimes used to keep off the heat from the cells containing the delicate microscopic creatures which are the subjects of experiments.

Refraction.—The rays of heat and light are endowed with the power of passing through many substances; and when it happens that these substances are of greater or less density than the medium just traversed, the rays are invariably broken out of their original course. This is called refraction; and we shall find that when the rays pass from a denser into a rarer medium, they are refracted or broken out of their course away from the perpendicular; and conversely, when they pass from a rarer into a denser, they are broken towards the perpendicular. This is illustrated by placing a coin in a basin, when the light reflected from the coin at the bottom of the basin reaches the eye in the direction of a crooked line, thereby giving rise to a notion that the coin is situated higher up against the side of the basin. A stick also looks crooked when partly immersed in water, by reason of the same cause; and it may be mentioned that a fisherman in spearing salmon, or a fish in striking at a fly, must always make compensation for this refractive power, or the object will be missed. The degree to which this takes place varies with the medium and the figure of its surface; but there is always the same relation for the same medium, between the angle of incidence and the angle of refraction. If these angles are measured from the surface instead of the perpendicular, and the former angle is called one, then the relative refractive powers or angles of different media will be as follows:—diamond, 2·54; sapphire and ruby, 1·78; topaz, 1·64; flint glass from 1·6 to 2·; crown glass, 1·58; rock-salt and rock-crystal, 1·56; alum, 1·46; the lens of the human eye, 1·38; fats and oils, 1·49; turpentine, 1·47; alcohol, 1·37; ether, 1·36; salt-water, 1·34; common water, 1·33; carbonic acid gas, 1·53; atmospheric air, 1·; oxygen gas, 0·92; and hydrogen gas, 0·47.

By taking advantage of this refractive power of transparent solids, we are enabled to construct instruments that have the power of diverting the rays of heat and light from their original course, and of bringing them to a focus. These instruments are called prisms and lenses: the former are triangular, square, or five-sided; the latter are

spherical, doubly-convex, plano-convex, doubly-concave, plano-concave, and concave-convex or meniscoid. Each of these has its own particular action; that of the doubly-convex and plano-convex is to focus the rays of light and heat when they are parallel, or to make them parallel when they are divergent. The bull's-eye of the policeman's lantern, and the lamps employed for signals at railway-stations, are constructed on this principle. They act by collecting the very divergant rays from the lamp, and throwing them in a parallel direction to a considerable distance.

Burning lenses have been used for a very considerable period of time; they are described by Aristophanes in his "Comedy of the Clouds," which was written about 430 years before Christ; but the most important facts connected with the focussing of the sun's rays have been investigated within the last century or so. Tschernhausen, in 1680, made several glass lenses of three or four feet in diameter; one of which weighed 160 lbs., and had a focus of twelve feet. Homberg employed it in the course of his inquiries, and found that when the sun's rays were focussed by it, he could burn up all the metals then known, and even melt slate and pottery. In the year 1773, a large lens was constructed in France under the direction of M. de Trudaine, and placed in the garden of the Infanta at the Louvre. It was composed of two large concave glasses, each four feet in diameter, with a radius of eight feet: they were joined together at the edges, and thus formed a chamber capable of holding thirty-five gallons of liquid. When filled with water they focussed the sun's rays at a distance of twelve feet; with alcohol at ten feet ten inches; and with turpentine at seven feet. The heating power of the apparatus was so great that it fused iron immediately. But the most splendid instrument of this kind was made a few years ago by Mr. Parker of Fleet Street: it was composed of flint glass, and cost about £700 in its manufacture. The heating power of the lens was enormous. Those who experimented with it, said it was as high as 1036° of Wedgewood's pyrometer, the zero of which is a red-heat. Some idea of its calorific power may be formed when it is stated, that with the rays of the noon-day sun it melted twenty grains of gold in four seconds, ten of platinum in three seconds, a topaz in forty-five, an emerald in twenty-five, a piece of flint in thirty, and a piece of pumice-stone in twenty-four seconds. Besides which it inflamed green wood and boiled water directly they were put into its focus.

Dispersion of Light and Heat.—When a ray of light or heat traverses any refractive medium, it is not only broken out of its course, but it is also decomposed, dispersed, or broken up into simpler parts. This is particularly evident in the case of light, and Newton was the first to direct attention to the fact. His mode of conducting the experiment, so as to demonstrate this, is still followed. If a beam of white-light enter a dark chamber and fall upon a triangular prism of glass, the beam will suffer both refraction and dispersion—that is, it will not only be broken out of its course, but will be split up into colours; and when these are received upon a screen of white paper, it will be found that the nature and order of the colours, beginning from the bottom or least refracted, are as follows,—red, orange, yellow, green, blue, indigo, violet. The image thus produced is called the Newtonian spectrum; and the colours were once thought to be the components of white-light; but a little attention to the subject will show that four out of the seven tints are compound, and that there are but three primitive colours—namely, blue, red, and yellow. The beautiful effect produced by the lustres of chandeliers is dependent on the dispersive power of the glass composing them; and in nature the rainbow, and the rich tints of the setting-sun, are examples of dispersion produced by the agency of water and the atmosphere. The three tints to

which we have alluded are called the complement of white-light; and whenever it happens that these are not present in the true proportion to form the light of day, there is a longing on the part of the eye for the full complement, and the organ of vision becomes fatigued and harassed if it is not gratified. To take an example: we soon feel tired if we exercise the eye by the light of gas; this arises from the circumstance that gas-light is too yellow, or rather reddish-yellow, in its tinge, and the eye longs for the blue rays to make up the complement. These can easily be supplied by means of blue glasses, or blue reflectors; and with such assistance, especially in the field of the microscope, where the eye is seriously tried, vision can be sustained for a longer period, and with greater comfort. In addition to the coloured beams which are thus produced by the prism, there are other rays that enter into the composition of white-light: these are the rays of heat and of chemical action. The former are chiefly located at a short distance below the red, although many are also scattered about in other parts of the spectrum. This has led opticians to believe that heat undergoes dispersion, and that there are different varieties of these rays, as in the case of light; but, from the circumstance of our not possessing an instrument or organ like the eye for judging of these differences, the opinion is founded rather on analogy than on actual experiment. The chemical or actinic rays are situated a little above the violet; and they are the agents that are concerned in the production of Daguerreotype and other light pictures.

Lenses, like prisms, also effect the dispersion of light; and hence in all the common kind of microscopes, telescopes, and opera-glasses, the object appears to be fringed with colours. This, however, is now corrected by a plan originally contrived by Mr. Dolland: it consists in the juxta-position of two lenses of different composition, one being made of flint-glass and the other of crown. By this contrivance the dispersion of one medium is neutralized by that of the other; and hence the object appears in its proper tints, with a sharp and well-defined outline.

Besides these properties of light and heat, there are others to which we can only refer; namely, those of *double refraction*, *polarization*, and of *being affected by a powerful magnet*. Double refraction is effected by passing the ray through a medium of unequal density, as in the case of calc-spar, when the object looks double; and polarization is accomplished by passing it through a tourmaline, or by reflecting it from different substances at certain angles. Finally, the magnetization of light and radiant heat are manifested when the rays are sent through certain media which are under the influence of powerful electro-magnets.

CANDLES.

ndle-Making.—It has been already remarked that candles are among the most ancient of illuminating agents, and it cannot be doubted that originally they were manufactured in a very rude way, by simply smearing a porous combustible solid with animal fat; but at the present time a number of fatty substances are employed in their manufacture, and great pains taken to have them as pure as possible. We have, for example, tallow and its derivatives stearine and stearic acid, margarine and margaric acid; palm oil and its constituents, palmitin and palmitic acid; cocoa-nut oil, cocinin and cocinic acid; spermaceti, wax, paraffin, &c. All these require to be purified before they can be converted into candles; and hence the necessity for

The *wicks of candles* are of three kinds, namely, the pith of a rush (*Juncus effusus*),

which grows abundantly in marshy places; and of cotton, which is either rolled into skeins or plaited into strands. The first is used for the common rush-light, the second for ordinary dips and for wax-lights, and the third for spermaceti, stearic acid, stearine, and other candles which do not require snuffing. In many cases it is necessary to prepare the wicks with a salt of ammonia, as the phosphate, borate, or sulphate, in order to keep them from clogging, and to give them a sufficient degree of rigidity to enable them to stand firmly up when they are burning. This was an improvement introduced in 1836, by M. De Milly, of Paris. Dr. Ure says that the best wicks are still imported from Turkey, and they are composed of skeins of unbleached cotton. The wick of wax mortars and night-lights are made of flax, as cotton is not able to resist the long-continued action of the high temperature of the flame.

Varieties of Candles and their Manufacture.—Two sorts of candles are commonly met with in commerce, namely, *dips* and *moulds*. The former are made by repeatedly dipping the wicks into melted fat, allowing a sufficient time between each of the dippings for the tallow or fat to cool. Usually the wicks are cut into proper lengths, according to the sort of candle to be made, and then suspended from a rod or frame, called a port; by this means the workman is enabled to dip a number of candles at the same time. In large establishments the ports or frames are attached to a revolving beam, so that, without much exertion, the workman can successively dip one port after another, and thus make from seven thousand to eight thousand candles in a day. The tallow is kept in the dipping-vessel at a temperature just over the setting point.

Mould candles are made in a tubular mould, which is either of pewter or glass. The mould consists of two parts, namely, the cylinder and the cap. The former is of the full length of the candle, and is highly polished in the interior, so as to allow the candle to slip easily out of it. The latter is a small cup, having a hole in the centre for the passage of the wick; it is fixed on to the bottom of the cylinder, and serves to give the taper-form to the top of the candle. Sometimes there is a third piece, called the foot, which is a sort of funnel, that is screwed on to the opposite end of the cylinder, and serves for the guidance of the melted fat into the mould. Eight or ten of these cylinders are usually fitted into one frame, which has the upper part formed into a trough for the reception of the melted tallow. The wicks are drawn into the cylinders by a hooked wire, and kept in their places by a wedge, which fixes them in the cap of the mould; the other end being held by a rod which passes across the frame. When all is ready, the liquid fat is run into the trough, and thence into the moulds, until each cylinder is full. After it has thoroughly cooled, the surplus fat is scraped out of the trough, and, the wedges being removed from the hole in the cap, each candle is drawn out of its mould by means of a hooked wire, which catches hold of the loose end of the wick. The candles are then cut of one uniform length, and trimmed up for the market.

The cheaper sort of mould-candles are those manufactured by Price and Company, and are made by machinery; eighteen candles being moulded at one time. The wicks are made in lengths of sixty yards; eighteen of these wicks are wound off upon eighteen separate rollers, and a roller is placed over each mould. The wicks having been passed through the cylinder, are seized at the lower end by a set of eighteen forceps, which draws them tight and fixes them in their places. The moulds, which during the operation have remained in a horizonal position, are now turned in a vertical direction, the small end downwards, and are passed upon a railway to the person who fills them. In their course they have traversed a hot closet, and have thus acquired a proper temperature for receiving the tallow. When full, they are pushed on to other railways, and allowed to

cool. This being accomplished, they are brought back in succession, by means of turn-tables, to their former places. The frame is then placed in a horizontal position; and eighteen plungers or pistons press forward the loose caps of the moulds, and thus push out the candles, and deliver the wicks for another operation.

Wax and Paraffine Candles are usually moulded by hand, in consequence of their sticking so tight to the sides of the mould, that they cannot be drawn out of it. The operation for wax candles is conducted as follows:—The wicks are first warmed in a stove, and then suspended to a hoop over the vessel of melted wax. The latter is then poured from a ladle over each wick in succession; and to prevent the wax from accumulating more on one side of the wick than the other, the wick is sharply rotated between the finger and thumb. When the candles are thus coated to about one-third their proper size, they are allowed to cool for a short time, and the operation is then repeated until they are half-made. This being accomplished, they are removed from the hoop, and rolled between two marble slabs until they are of one uniform thickness. The upper end of each candle is now formed by cutting it down to a metal tag, which covers one end of the wick. The candles are then again suspended to the hoops, but in a reversed position; and the operations of basting and rolling are repeated as often as necessary. Finally, the lower ends of the candles are cut square, so as to make them of the desired length.

The large wax candles used in churches are formed by rolling the wick in a thin layer of wax, and then, after adding layer after layer, it is finished off in the usual way.

Long wax tapers are made by winding the wick on a drum, and then leading it by means of a guide-roller into a trough of melted wax, from which it passes through a series of holes progressively smaller and smaller on to a second drum, where it is wound up—the operation being somewhat like that of wire-drawing. A little turpentine is added to the wax to render it pliable, so that it may not crack as it bends over the drum.

We proceed now to speak of the different kinds of fats, and of the candles made from them.

Tallow is obtained from animals; it is the fat which is located under the skin, about the intestines, in the bones and muscles, and around the kidneys. It is extracted by cutting the tissue into small pieces, then submitting it to heat, and finally to pressure. The tallow or fat of bones and the dressings of skins is obtained by boiling them in a large caldron, and skimming off the fat as it rises to the surface. A large quantity of tallow is obtained from meat during the ordinary operations of cooking; and this is known in commerce by the name of kitchen-stuff. Tallow, when first obtained, has a very disagreeable smell; indeed, it contains a great number of impurities, as blood, animal tissue, water, &c.; and in this condition it is not suited for the manufacture of candles. To render it pure, it is submitted to various operations, which are called *rendering*. One of these is as follows:—The tallow is melted in a large copper set upon an open fire, and the water contained in the impure fat is boiled away; during this stage of the operation the animal tissues and bloody matters coagulate and rise to the surface. These are strained off and pressed, the residue is sold under the name of greaves or cracklings, and is used for feeding dogs. Another mode of rendering is to submit the melted tallow to the action of steam, which is blown into it from a pipe pierced with a number of holes. But the most effective process of all is that recommended by M. D'Arcet: the tallow is melted by steam-heat, and then treated with very dilute sulphuric acid; this destroys the colouring matter, and separates the animal tissue in the form of black flakes, which

speedily settle to the bottom of the vessel. After drawing off the tallow, and washing it well with warm water, it is allowed to stand until it rises to the surface and is cold. In this state it is nearly free from colour and smell. Some years ago Mr. Watt obtained a patent for purifying tallow by a mixture of acids, as sulphuric, oxalic, nitric, and chromic; the two latter of which give out oxygen gas, and thus bleach the fat.

Tallow consists of several fats; one of which (oleine) is liquid at ordinary temperatures, and the others (margarine and stearine) are solid. Occasionally also, when it has been obtained from particular animals, it contains a few other fats, as hircine, butyrine, &c. The relative proportions of these fats give to tallow its different consistence; for example, beef-marrow or bone-fat, which is rather hard, contains 76 of stearine to 24 of oleine; mutton fat, 62 to 38; beef fat, 54 to 46; butter, 40 to 60; hog's-lard, 38 to 62; goose fat, 32 to 68; and turkey fat, 26 to 14. Again, this melting point of different tallows varies with the proportions of these constituents; for while common tallow melts at from 94° to 104° Fah., marrow fat requires a temperature of 115° to liquefy it, and hog's-lard is fluid at 81°.

Most of the tallow imported into this country comes from Russia; a large quantity also arrives from South America, Australia, and the United States of America. Some idea may be formed of the relative proportions supplied to us from those countries by the following table, which shows the amount of tallow imported into England in 1850:—

Russia	803,697	cwts.
South America	184,321	,,
Australia	179,567	,,
United States	32,523	,,
Other parts	18,993	,,
Total	1,219,101	,,

In addition to which 1,067 lbs. of tallow candles were imported from various places.

Three sorts of candles are made out of ordinary tallow; namely, rush-lights, dips, and moulds. The former are not much employed in towns, except for watch-lights; but they are still the favourite candle with the poor in country villages; and it is very probable that they are chosen because of their not guttering so much as the common dip when they are exposed to currents of air: besides which, they burn longer, and are therefore more economical. In many cases these candles are made by the peasants themselves. Mr. Gilbert White has given an account, in his "Natural History of Selbourne," of the manner in which they are produced by the cottagers of Hampshire. They take a quantity of rushes, which have been previously peeled, and dip them into the melted tallow, so that six pounds of tallow shall serve for 1600 rushes. In this way they produce candles which require 228 to make a pound. The rushes are peeled on three sides for the best lights, and on two only for watch-lights, and which, says Mr. Gilbert White, only shed a dismal one—darkness visible. Of the other kind, a good one, which measured 2 feet 4½ inches in length, burned 57 minutes; and he was assured by an experienced old housekeeper that 1½ lb. of rushes, after having been coated with tallow, completely supplied her family for a year. The cost of lighting with rushes he estimated at one farthing for 5½ hours; whilst a halfpenny candle, in the blowing, open rooms of the poorer classes, only lasted two hours. The rush-lights that are sold in London vary from ten to eighteen in the pound. A specimen of ten to the pound, which measured

11½ inches in length, burnt at the rate of 1¼ inches in the hour, or 74 grains, and it took five of them to give the light of one sperm of 120 grains per hour.

Ordinary dips burn with great irregularity—even the same candle will vary from 120 to 180 grains per hour; and when consumed at the standard rate, they give a light which is just one-third that of sperm. Dips are made of all sizes from six to sixteen in the pound; and they are sold at from *5d.* to *7d.* per pound.

Mould candles of tallow are generally made of the better description of fat—they are therefore whiter than dips, and melt at a little higher temperature. A mould candle of six to the pound burns at the rate of about 143 grains per hour, and its illuminating power is rather more than half that of a sperm of 120 grains; so that, weight for weight, its powers is about half that of sperm.

The disadvantages attending the use of tallow candles are, that they melt at a very low temperature, and are therefore not suited for warm climates or hot rooms; they gutter when they are exposed to draughts; they constantly require snuffing; they give out an unpleasant smell, both before burning and after; they soil the hands and grease everything with which they come into contact; and in warm weather they are very apt to break. Some of these disadvantages have been overcome by the chandlers of Dublin, many of whom have acquired a high reputation for the superior quality of their mould candles; and it has been found that by waxing the wicks before they are used for making the candles, the disposition to gutter, which is so objectionable, is in a great degree prevented. Candles of this description generally fetch from a halfpenny to three farthings a pound more than the commoner sort.

Palm oil is the produce of the *Elais Guiniensis*, or *Avoira elais*, a palm that grows very abundantly in the tropical parts of Africa. Most of the palm oil that we receive into this country comes from the western coasts of that continent—chiefly from Guinea. It is obtained by crushing the fruit, then submitting it to the heat of boiling water, and finally to pressure. The oil has a buttery consistence, is of an orange-yellow colour, a sweetish taste, and an agreeable odour. When new it melts at a temperature of 81° Fah.; but if old, it requires a heat of from 90° to 96° to liquefy it. It consists of about 69 of oleine, and 31 of a solid fat named palmitine. The crude oil is readily bleached by exposing it to light and air, or to chlorine gas, and it may also be purified in the same way as common tallow. Until it is deprived of its great excess of oleine, it is not fit for the manufacture of candles. The quantity of palm oil annually imported into this country amounts to about 500,000 cwts. In the year 1849 it amounted to 493,331, of which 475,364 came from the western coast of Africa; 13,349 from the United States; 3,719 from the Canary Islands; 525 from the Brazils; 353 from Madeira; and the rest from Naples and Sicily. The late war, and the consequent deficiency of Russian tallow, led to large increase both in the demand and in the price of palm oil.

Galam or Ghea butter is another fat oil that closely resembles palm oil: indeed, it is very often mistaken for it. It comes from the western parts of Africa, and is the produce of a palm, the *Micadenia* or *Bassia Parkii*—a tree that is very similar in its appearance to the *Bassia latifolia*, and the other species of *Bassia* that are indigenous to the province of Hindostan. According to Park, the tree is very abundant in Bambara; and the oil is obtained from the fruit in the same way as palm oil. Ghea is of a greyish-white colour; it melts at a temperature of 97° Fah., and consists of about 68 of oleine, and 32 of a solid fat like palmitine. It is used for the same purposes, and in the same way, as palm oil.

Cocoa-nut oil or fat is extracted from the kernel of the common cocoa-nut, which is the fruit of a palm named *Cocos nucifera*. The oil is semi-fluid, or rather buttery, in its consistence. It melts at a temperature of 68°, and contains two or more fatty principles, one of which, namely, the oleine, amounts to about 71 per cent., and the other, cocine or cocinine, to 29. The oil is not fit for the manufacture of candles until it has been submitted to cold and pressure. We import this oil from several parts of India, from the islands of the Pacific, from Australia, and from Borneo. In the year 1850, the quantity shipped to this country amounted to 98,040 cwts.; of which 85,096 came from India; 6,315 from Australia; and the remainder from Borneo and other places.

Several kinds of vegetable fats or butters, well suited for the manufacture of candles, have at various times been sent to this country; but the demand for them has not been sufficiently great to encourage a trade. Among these may be mentioned the solid fats obtained from three species of *Bassia*, indigenous to India. These are, *Ilpa oil*, or *Eloopei unnay*, which is expressed from the seeds of the Illupie tree, or *Bassia longifolia*—a tree that is very abundant in the Madras Presidency, and in the southern parts of Hindostan. This oil is white, and it requires a temperature of from 70° to 80° to melt it. Similar fats are obtained from the seeds of *Bassia latifolia*, of the Bengal Presidency, and *Bassia butyracea*, of the province of Dotee—the former is named *Epie* or *Mahowa seed oil*, and the latter *Phoolwa* or *vegetable butter*. A solid oil, of a pale greenish colour, is obtained from the tallow-tree of Java—probably a species of *Bassia*, which is common not only to Java, but also to the western countries of the Archipelago. In fact, it appears from the observations of Mr. Lowe, that several kinds of solid oil are obtained in the islands of the Archipelago from different species of *Dipterocarpus*. These oils are hard, yellowish-green, and brittle, and they melt at about 90° of Fah. An oil named *Piney tallow* is expressed from the fruit of the panoe tree (*Vateria indica*), which grows abundantly in Malabar and Canara. The oil is white, solid, and fusible at 97°; it makes excellent candles, which do not give out any unpleasant smell in burning. *Cocum oil*, or *Kokum butter*, is obtained from the seeds of a kind of mangosteen (*Garcinia purpurea*), which is common in several parts of the peninsula. It is of a pale greenish-yellow colour, and it melts at 95°. *Kali-ziri*, or *Khatzum butter*, another variety of fat oil, is in all probability the produce of the seeds of *Vernonia anthelmintica*, or of *Salvadora persica*, both of which are common in Guzerat and Concan Ghats; it is a bright green oil, of the same fusibility as the last. The seeds of *Carapa Guianensis*, of Guiana and Acagie, yield a semi-solid oil named *Crab* or *Carapa oil;* and, lastly, a solid fat called *Neem oil*, or *Vaypum unnay*, is obtained from the ripe fruit of the margosa tree (*Melia azadirachta*). All these fats might, if necessary, be largely supplied to this country, and thus be the means of keeping in check the high price of tallow, or even of taking its place altogether.

Stearine, Margarine, Palmitine, Cocine or Cocinine, &c., are the names applied to the solid fats contained in tallow, suet, lard, palm oil, ghea butter, cocoa-nut oil, &c. It has been already stated that none of the raw fats, except tallow, can be applied at once to the manufacture of candles; but they must be subjected to certain processes in order to remove the oleine or liquid constituent, and so obtain the fats in a more solid state.

As far back as the year 1799, Mr. William Bolt took out a patent in this country for the manufacture of candles from compressed tallow. This perhaps was the first attempt ever made to improve the quality of candles by fabricating them from the solid constituents of fats and oils. About twenty years after this, the researches of Chevreul

gave an impetus to the discovery of Bolt, by showing that all the fats consisted of at least two proximate elements—namely, an oily or liquid portion, which he named oleine, and one or more solid constituents which he called stearine, margarine, &c. Taking advantage of this fact, the candle-makers soon adopted a process whereby they were enabled to separate the one fat from the other, and thus to procure a material which would not melt at so low a temperature as ordinary tallow. To effect this the tallow, palm oil, or cocoa-nut oil is melted, and then allowed to cool as slowly as possible, taking care that it is constantly agitated during the whole time that it is setting. When the mass has acquired a pasty consistence it is transferred to horse-hair or linen bags, and submitted to great pressure. In this manner the oleine is squeezed out, and the solid fats are left in nearly a pure state. By repeating tke process of liquefaction and pressure, the stearine, margarine, palmitine, and cocinine are obtained still purer. In this condition they are perfectly white, hard, and nearly free from greasiness, and they melt at a much higher temperature than the original fats; for example, common tallow melts at from 99° to 104° of Fah., whereas stearine, which is obtained from it, melts at 144° and margarine at 117°. Palm oil is fluid at from 90° to 96°, but palmitine requires a heat of 124° to melt it; and lastly, cocoa-nut oil is liquid at 68°, while its solid constituent cocine or cocinine is fusible at 110°. These fats are employed in the manufacture of *composition* and *Palmer's candles*. The former burn at the rate of from 140 to 155 grains per hour, and they furnish a light which is scarcely inferior to sperm; the latter have an average consumption of about 160 grains per hour for each wick, and the light emitted is in the same ratio as the former.

Stearic, Margaric, Palmitic, Cocinic, and other solid Fatty Acids, are obtained from the preceding; indeed, the solid fats which have just been described contain in each case a still more solid compound, which bears the name of the fat from which it is derived. These acids were discovered by Chevreul in the year 1823; and two years afterwards he thought them of so much importance, that he allied himself with Gay Lussac, and took out patents in this country and in France for their manufacture. But, notwithstanding that they furnished candles of the very best description, and have since been made the basis of most profitable speculation, they did not realize any advantage whatever to the original patentees; in fact, the processes of Chevreul and Gay Lussac were so complicated and expensive, that they could not be followed out with profit or advantage: in addition to which, it was found that the candles manufactured from the fatty acids would not burn with an ordinary wick; and hence the necessity for still further improvement in this direction. Cambaceres, however, overcame this difficulty by inventing the present description of plaited wick; and this was afterwards improved by De Milly, who suggested the use of boracic acid and the salts of ammonia for impregnating the fibres of the cotton. Another obstacle to the use of the fatty acids was the pertinacity with which they crystallized; thus rendering the candles brittle, unsightly, and irregular of combustion. An attempt was made to remedy this by introducing fine powders into the melted acids, so as to break their grain; but then it was necessary to use powders of a volatile nature which would not clog the wick, and in an unfortunate moment they made choice of white arsenic. The introduction of this deadly poison into candles soon created alarm, for they produced very injurious effects on those who inhaled the vapours of combustion; and, in fact, it brought the discoveries of Chevreul into so great disrepute, that it almost annihilated the infant art of stearic candle-making. "It is true," say the jurors in their report on the candles of the Great Exhibition, "this deleterious substance was

added in very minute quantities, yet it was entirely incompatible with health, and was soon prohibited on the continent by authority, and in England by equally powerful public opinion. Here commenced all the manufacturer's troubles anew. In all directions he sought a substitute, and yet found none: at last, after innumerable experiments, and when almost driven to despair, he hit on two simple expedients that answered the purpose in the most admirable manner. Those were the addition of a very minute quantity of wax to the melted fatty acids, or the allowing the acids to cool almost to the point of congelation before they were poured into the moulds. By this means a sort of liquid pulp is obtained, which sets in the moulds without crystallizing. This is the plan adopted in the present time; the melted acids being constantly stirred during their congelation, and the moulds warmed to a temperature of about 110° Fah. before the semi-fluid mass is poured into them.

The preceding account is, however, but a mere outline of the progress that has been made during the last twenty years in this important branch of industry. It may be now said that it engages a larger capital and occupies more attention than all the other modes of candle-making put together. In this country, for example, there are two companies—namely, Price's and the British Sperm, which produce annually about 2000 tons of stearic candles. In Austria the Apollo and Milly Companies furnish to commerce at least 1600 tons per annum. In France there are about twenty-five companies, which produce no less than 7800 tons of stearic candles in the year; and in Belgium, Spain, Prussia, Denmark, Holland, Norway and Russia, there are, on the average, about 500 tons manufactured in each country during the twelve months.

Two, if not three, distinct processes are employed at the present time for the preparation of the fatty acids. These are the saponification process of De Milly, and the oil of vitriol process of Fremy; besides which there is a modified process of De Milly's which is practised by Jaillon, Monier, and Co., at La Villette, near Paris.

The saponification process is founded on the discoveries made by Chevreul in the year 1823, namely, that when fatty matters are boiled with potash, soda, or lime, they are converted into soap by the union of the fatty acids with the alkali; and from this soap the acids may be obtained in a more solid condition by the action of a stronger acid, as sulphuric or muriatic. Chevreul saw the importance of his discovery, and took out a patent for the manufacture of the acids from soaps made with potash or soda. These, however, were found to be far too expensive; and in the year 1831, De Milly directed attention to the use of lime. From that date until now the process has been gradually advancing towards its present state of perfection.

The following is an outline of the process as it is conducted at the works of the Apollo Company, at Vienna; of De Milly, in Paris, Brussels, and Vienna; and of the British Sperm Candle Company, in this metropolis. The process is divided into three stages, namely, the saponification of the fat; the decomposition of the soap by a strong acid; and the removal of the liquid oil and other impurities by means of pressure.

(*a.*) *The saponification of the fat* is effected by melting the tallow, or the palm oil, in a large vat, by means of steam which issues from a pipe perforated with holes, and then stirring in a quantity of lime in the state of thin cream; 10 or 15 parts of dry lime being used for every 100 of fat. The mixture is kept in a state of ebullition for five or six hours, or until it is completely saponified. It is then allowed to stand, in order that the impurities may settle to the bottom, and the melted soap rise to the surface and cool. The soap thus formed is very hard, and is generally called rock. It is ground to a coarse powder, and is then ready for the next operation—

(*b.*) *The decomposition of the soap by a strong acid.* The ground rock-soap is placed in wooden vats lined with lead, and, after being drenched with water, it is raised to a boiling temperature—the heat being applied in the same way as before. At this moment the soap is treated with dilute sulphuric acid, using about 25 of the strongest acid to every 100 of tallow or palm oil. In this way the soap is decomposed; its lime unites to the acid of the vitriol to form sulphate of lime, or plaster of Paris, which either dissolves in the water or else settles to the bottom of the vat, while the fatty acids are set free and float to the surface. These are called "yellow matter;" and, after having been well washed with warm water, they are poured off into vessels called "jacks," and from thence into shallow tin pans, where they cool.

(*c.*) The cakes thus obtained consist of the solid and liquid acids of the fat; to separate which they are placed in horse-hair bags, and subjected to hydraulic pressure, gradually increased up to about six hundred tons. This is extended over a period of six or eight hours, during which the liquid oleic acid runs out and carries with it the brown colouring matter of the fat, leaving the solid fatty acids in a nearly pure condition. It is generally thought necessary to remelt the acids, and to treat them with a little dilute sulphuric acid, so as to remove iron and other impurities that may have been acquired in the art of pressing. After this they are again cast in shallow pans, then placed in bags, and submitted to a more moderate pressure of about forty tons. During the last operation the cakes are slightly warmed in an atmosphere of steam, so as to facilitate the removal of the last portion of oil. In this way a solid mass is obtained which has all the appearance of ivory; and the product amounts to about thirty per cent. of the fat originally used.

The second or vitriolic acid process for obtaining the fatty acids was originated in 1836, by M. Fremy, who discovered that these acids have the power of combining with concentrated sulphuric acid, to produce compounds which are named sulpho-stearic, sulpho-oleic, sulpho-margaric, sulpho-palmitic, and sulpho-cocinic acids. These are readily decomposed when they are brought into contact with boiling water, the vitriolic acid being dissolved by the latter, while the fatty acids are set free and float to the surface. This fact was made the basis of two patents, which appeared in the year 1840. One of these was taken out by Mr. George Gwynne, who proposed that the fats should be separated from the acid by distillation; and the other was obtained by Mr. George Clark, who advised that the acids should be set free by simply washing the product. But neither of these patents produced successful results; and it was not until the year 1844 that the process was so perfected by the labours of Jones, Wilson, and Gwynne, as to be applicable to the purposes intended. In that year the names of Wilson and Gwynne are found associated in a patent which still continues to be in force. The process adopted by those patentees is now extensively practised at the works of Price's Candle Company, at Vauxhall and Battersea; and at those of MM. Masse and Tribonillet, at Paris; of Motard, at Berlin; of Bert, at Gijon, in Spain; and at one of the works of the Milly Company, at Vienna.

The fats usually employed for this purpose are, palm oil, refuse grease from gluemaking and bone-boiling, and ordinary tallow. The process is as follows:—

1st. *The Decomposition of the fat with Sulphuric Acid.*—This is accomplished by first melting the oil or fat in a leaden vessel by the aid of steam, then allowing it to stand for a short time in order that the mechanical impurities may subside. The liquid fat is now pumped into another vessel and heated to a temperature of 350° Fah. While in this state it is subjected to the action of strong sulphuric acid—using about 6 lbs. of acid to

112 lbs. of palm oil. The acid quickly decomposes the oil and gives it a black colour. It is now drawn off from the acid, and transferred to a washing tank, where it is boiled up with water by means of a jet of steam. After two or three washings it is ready for the next operation.

2nd. *The Distillation of the fatty acids by means of very hot steam.*—The dark liquid fat of the washing-tank is conveyed into a copper still, where it is heated to a temperature of 560°, and submitted to the action of steam that has been heated to a very high degree by passing through a system of pipes set in a furnace. The hot steam raises the fatty acids into vapour, and carries them over into a series of vertical pipes, which act as condensers. These are kept at a temperature of 212°; and consequently they retain the fatty acids, but do not arrest the steam. Towards the end of the process it is necessary to elevate the temperature of the furnace in which the still is set, and also to raise the heat of the steam in order that the whole of the fatty matter may be distilled over. The residue in the still after this operation looks like pitch, and may be employed for the same purposes.

3rd. *The cold and hot pressing of the fatty acids.*—These are effected in the same way as that described in the saponification process.

The other process to which we have referred—namely, that portion at the works of Jaillon, Monier and Co., at La Villette, near Paris, is a modification of De Milly's lime process. It consists in passing a rapid current of sulphurous acid into the lime vat while the rock mass is forming; and thus of increasing the amount of solid fat by the conversion of the liquid oleic acid into solid elaidic. In this way the very commonest tallow may be used, for the sulphurous acid acts as a bleaching and deodorizing agent. The subsequent stages of the process are the same as De Milly's.

Lastly, it may be said that a large quantity of the fatty acids which enter into the composition of ordinary soap are obtained at the grease-works of Mr. Banwens, at Wakefield, from the waste lyes and suds of the woollen, silk, and cotton manufactories. It is calculated that about 11,000 tons of fat and oil are annually expended in this country in the cleansing and preparing of the fabrics in question. Hitherto all this had been allowed to run to waste; but the energies of Mr. Banwens having been directed to the subject, it is hoped that the larger portion of the fatty acids contained in the soap and oil will be retrieved. These acids are worth about £15 a ton; and if only half of them are annually recoverable, as much as £93,500 will be annually secured. The acids are obtained by treating the boiling suds with a little oil of vitriol or spirits of salt—the liquefied fats rise to the surface, and when cold may be skimmed off or otherwise collected. The fats are then cast into blocks and pressed in the usual manner.

In whatever way the solid fatty acids are obtained, they always present the following characters:—They have the appearance of ivory, or of fine spermaceti: they are inodorous, and do not communicate a greasy stain to paper or soil the fingers: they melt at a much higher temperature than the original fats: indeed, the melting-point of pure stearic acid is 167°; that of bassic acid, which comes from the palm fats of India, is 159°; that of palmitic and margaric acids 140°; and that of cocinic acid from cocoa-nut oil is 110°. It rarely happens, however, that these acids are obtained perfectly free from a small proportion of liquid oleic acid; and hence the melting-points of the acids, as found in commerce, are a little below the preceding. Stearic candles generally melt at from 130° to 132° Fah.

The candles made from these acids are much in vogue. They are known by the names of *British sperm*, *Paris sperm*, *Belmont sperm*, *Fairfield sperm*, *Victoria Regia* or

Victoria sperm, and *Bougies de l'etoile* or *Bougies du phare*; and when tinted with a little gamboge they are called *British wax*, *Fairfield wax*, or *Paris wax*. Their prices vary from 1*s.* to 1*s.* 3*d.* per pound. The candles of six to the pound burn at the rate of from 140 to 144 grains per hour, and they give a light as nearly as possible the same as sperm. If there be any difference, the light of sperm is a little greater, and that of stearic acid a little whiter. When calculated into an average consumption of 120 grains per hour, it will be found that, for equal weights consumed, 15 sperm candles will give the light of 16·5 stearic. The advantages which are attendant on the use of these candles are, the great regularity of their burning, the dryness of the cup below the flame, the absence of all disposition to gutter, their not softening in warm climates or hot rooms, and their not soiling the fingers or clothes. It is very probable that stearic candles will, ere long, supersede every other description of *bougie*.

The candles which are manufactured by Price and Co., from the fatty acids obtained by the distillation of *Chinese vegetable tallow*—the product of *Stillingia sebifera*—are even more infusible than the last; for they require a temperature of 136° to liquefy them. A patent has been taken out by Messrs. Wilson, Gwynne, and Wilson, for the manufacture of candles from this material.

Composite or Composition Candles.—These are of very uncertain composition. Some are made from the crude fatty acids that distil over during the second stage of the oil of vitriol process; others are made of stearic acid, stearine, and the solid part of cocoa-nut oil. The former are the composite candles of Price and Co. They are very greasy to the feel; they gutter whenever they are exposed to a draught; they melt at a temperature of from 104° to 118°; and they burn at the rate of from 141 to 155 grains per hour. The average illuminating power, when reduced to the standard consumption of 120 grains per hour, is one-sixth less than that of sperm. In fact, it takes 20 of the worst kind of composite candles, or 16 of the best, to give the light of 15 of sperm. The other kind of composition candles is not so fusible as the last, and they are superior in many respects. Composite and composition candles vary in price from 8*d.* to 11*d.* per pound.

Spermaceti.—This remarkable fat is chiefly obtained from the great spermaceti whale, or great-headed cachalot (*Physeter macrocephalus*), which inhabits the Pacific Ocean, the Indian Ocean, and the China Sea. It is also obtained from other species of cachalot, as the *Physeter cetadon*, *trumpo*, *cylindricus*, *microps*, &c.; and from the two kinds of dolphin, viz. the *Delphinus tursio* and *edentulus*. The spermaceti is found in all parts of the bodies of these animals, mixed with the common fat or blubber; but the great receptacle for it in the *Physeter macrocephalus* is a large excavation or case, situated in the upper jaw, directly in front of the skull and above the nostrils. This receptacle is opened by the whalers directly the animal is captured; and the liquid contents, consisting of oil, spermaceti, and cellular matter, are dipped out. The dense mass of cellular tissue, called junk, which lies immediately beneath the case, is also removed; and when boiled, it furnishes an inferior kind of oil and spermaceti. The contents of the case are carefully boiled, and then strained off into casks. In this state it goes by the name of "head-matter"; and is composed of spermaceti and sperm oil. After standing for some time at a temperature of from 40° to 50° Fah., the spermaceti solidifies as a dirty-brown crystalline mass. This is separated from the oil by straining through bags, and pressing. The crude spermaceti is melted by the aid of steam, and then allowed to cool very slowly; after which it is ground to powder, placed in bags, and subjected to enormous pressure—a pressure of six hundred tons. In this way the residue of the oil is squeezed out of it, and the spermaceti which remains

is nearly white. To purify it still more, it is melted in a large iron vessel, and boiled for some time with a solution of caustic soda. This has the effect of converting all the oil with which it is contaminated into a soap, which dissolves in the water, while the spermaceti floats to the surface. It is now run into tin pans and allowed to cool. The mass so obtained is crushed to a powder a second time, and then pressed as before; the operation being conducted in an atmosphere heated by steam. Finally, the spermaceti is boiled with a strong solution of potash; and when it is perfectly limpid and colourless like water, it is cast into square blocks.

In this condition it is named *cetine:* it is a white crystalline solid, with a pearly lustre and greasy feel. It melts at a temperature of 120°; and it consists of a fatty acid (*cetylic*), which fuses at 131°, and a species of alcohol, named *ethal*, which melts at 118°. Impure kinds of spermaceti liquefy at from 112° to 160°.

Spermaceti candles contain about three per cent. of wax, which is added to break the grain or to prevent crystallization. A sperm candle of six to the pound burns with great regularity if it is properly made; but those in commerce at the present time are but poor examples of what such candles should be, for they range in combustion between 120 and 146 grains per hour. A spermaceti candle of six to the pound, burning at the rate of 120 grains per hour, is generally taken as the standard of comparison for all other illuminating agents, for the light emitted is clear, white, and very brilliant. The candles which are sold under the name of *transparent wax* are only sperm candles coloured with a little gamboge. The price of sperm candles is from 2*s.* to 2*s.* 2*d.* per lb.; the best varieties have a slightly bluish tint, and they ought not be become greasy in the warmest room. The quantity of spermaceti made use of in this country is not very considerable. In the year 1850, 5,792 tons of head-matter were imported, besides 1,120 lbs. of spermaceti, and 728 lbs. of sperm candles.

Wax is obtained from several sources: it is secreted between the abdominal scales of the honey-bee, and formed by that insect into honey-comb. The insect wax of China is produced by the male of the *Coccus ceriferus*, which deposits it on the trees on which it feeds, especially the *Rhus succedaneum.* A soft, tenacious, mahogany-coloured wax is obtained in great quantity at the Brazils, and is the product of a black bee which hives under ground. Vegetable wax is procured from the berries of several myrtles (the *Myrica cerifera*, *augustifolia*, *latifolia*, *&c.*), which grow abundantly at the Cape of Good Hope, and in South America: besides which, there are many trees in Japan and St. Domingo which yield substances resembling wax; these are the *Croton sebiferum*, *Celastrus ceriferus*, and *Ceroxylon audicola.* A wax-like substance, named *cerosine* by Dumas, is also obtained from the surface of many species of sugar-cane; and Mulder informs us that the skins of apples and the berries of the mountain-ash yield abundance of wax: in fact, wax is a very common product of the vegetable kingdom—it forms the bloom of fruits and of young leaves, and it is a large constituent of the green and yellow colouring matter of plants (*Chlorophylle* and *Xanthophylle*).

The wax of English commerce is procured from honey-comb: the comb being first allowed to drain in order to remove the honey, after which it is boiled up with water, and permitted to stand until cold, when the wax solidifies upon the surface in a brownish-yellow cake. This is purified and bleached by the following processes:—The wax is cut by machinery into very small fragments, and put into a vat with water and a little concentrated sulphuric acid,—the proportion of acid being a pint to a ton. Steam is then blown into the vat by means of a coiled pipe pierced with holes; and the mixture is kept in constant agitation. After a time it is allowed to stand quiet, when

the impurities subside to the bottom, and the wax floats to the surface as a clear and almost colourless liquid. It is now run into a trough named a cradle, which has a number of holes about the size of a quill in the bottom of it. This trough is placed over a drum or wooden cylinder, which revolves in a tank of water: the melted wax, running in small streams upon the revolving wet drum, is floated off upon the surface of the water in the form of exceedingly thin strips or flakes, called ribbons. These are collected at the opposite end of the tank; and after being drained in baskets, they are spread out upon tables, and exposed to the air and light to bleach. This occupies a period of from five to ten weeks, during which the flakes are frequently wetted and turned. They are also melted and ribboned once or twice during the process, in order that fresh surfaces may be exposed, and the whole acted on in one uniform manner. When the wax is sufficiently white it is melted in vats and cast into thin cakes.

Different kinds of wax bleach with different degrees of facility: thus the wax of England, Hamburg, Odessa, Portugal, Mogadore, Zanzibar, the East and West Indies, and North America, bleach very rapidly; while those of Cuba, Dantzic, Kœnigsberg, Gabon, and Gambia, bleach with difficulty; and the soft mahogany-coloured wax of the Brazils cannot be bleached at all.

Pure wax is solid up to the temperature of 148°, but unbleached wax melts at from 144° to 146°. It contains about twenty-two per cent. of a peculiar fatty acid (*cerotic*) which was formerly named *cerine;* and the remainder consists of a compound substance named *myricine*, which Mr. Brodie says is composed of the solid acid of palm oil (*palmitic*) and a species of alcohol which he has named *oxide of melissyl*. Chinese wax is entirely free from myricine, and is made up of cerotic acid and an alcohol named *oxide of cerotyl*. Cerine and myricine are distinguished from each other by the following properties:— Cerine is soluble in boiling alcohol, from which it is deposited as the spirit cools; but myricine is wholly insoluble in that menstruum. Cerine melts at from 162° to 172°, while myricine fuses at as low a temperature as 147°.

Wax candles are rarely composed of pure wax, but consist of wax and stearine or stearic acid in various proportions. The candles of commerce are very irregular in combustion; in fact, they burn from 135 to 175 grains of wax per hour; and they give a light which varies from one up to three, according to the condition of the wick. At the best of times the light of wax is, weight for weight consumed, about one-sixth less than that of spermaceti. The cost of wax candles is from 2*s.* 2*d.* to 2*s.* 4*d.* per lb.

We do not employ much wax in this country for candle-making, as preference is now given to sperm and stearic candles; but on the continent it is still made use of to a great extent in the fabrication of candles for religious purposes, and also for holiday and fête occasions. In the Greek Church wax and oil are the only illuminating agents allowed; and in the Romish Church large wax tapers are also employed during divine service. These, as well as the candles for weddings, fêtes, and saint-days, are generally ornamented either with spirals of gold, or with different devices in colours,—the colours being artificial ultramarine for blue; a mixture of verdigris and emerald green, or verdigris alone, for green; chromate of lead or gamboge for yellow; vermillion for red; and madder lake or alkanet root for pink. The best description of candle manufactured from wax is the *mortar-light*, which is used either for night-watching or for heating dishes on the table. On the continent these lights are termed *veilleuses*.

The quantity of crude wax imported into England during the year 1850 amounted to 10,751 cwts.; besides which there were 1,076 lbs. of wax candles imported. Most of our wax is received from Gambia. In Russia, where there is a large consumption of

wax in the religious services of the Greek Church, as much as £60,000 are annually expended in wax candles.

Paraffine.—About twelve years ago the sagacity of Liebig led him to remark that "it would certainly be esteemed one of the greatest discoveries of the age, if any one could succeed in condensing coal-gas into a white, dry, solid, odourless substance, portable and capable of being placed upon a candlestick or burned in a lamp."—(Familiar Letters on Chemistry, page 158.) In the course of the last few years this grand result has been effected; indeed, we may say that the germ of the discovery was brought to light more than twenty years ago by the researches of Reichenbach and Christison. The former of these chemists showed that the thick heavy oil procured by the distillation of tar from beech-wood, contained a solid crystalline body which he named *paraffine;* and the latter, in examining Rangoon petroleum, discovered a substance which he called *petroline.* Both of these compounds are identical in their chemical composition with the illuminating principles of coal-gas, and they are now known to be one and the same thing. The term paraffine is still employed to designate the substance, in consequence of its weak affinities (from *parum* little, and *affinis* affinity). Since that time it has been procured by Mr. Rees Reece and Sir Robert Kane from peat; by M. Ettling and Mr. Brodie from wax; by Mr. Young from Boghead coal; and by others from the bituminous schists of England, France, and Germany. In all cases it is obtained by destructive distillation; and the following are the processes which are commonly employed.

The plan proposed by Reichenbach was to distil wood-tar to dryness, and to separate the heavy oil which is thus obtained from the water and light oil that also come over during the process. This is distilled a second time, and only the last portions are retained. These are treated with concentrated sulphuric acid, then with water, and finally with boiling alcohol, from which the paraffine separates in the form of crystalline plates as the spirit cools.

Mr. Reece's process is to distil peat in a sort of blast furnace, to the top of which a condensing worm is attached. The air supplied at the bottom of the furnace keeps up an imperfect combustion of the peat, and the products are conveyed into the worm, where they are condensed. The greasy tar which subsides is collected and heated to a temperature of 100°; it is then submitted to the action of strong sulphuric acid, and afterwards boiled in water. The paraffine collects on the surface, and solidifies as the water cools. It is now ready for distillation; and when so treated it furnishes three products—namely, a very light oil (*eupion*), which first comes over, then a heavy oil, and finally paraffine. The light oil is separated from the mixture of the other two by decantation. When the latter is allowed to cool, the paraffine separates in the form of very minute grains; and on submitting the pasty mass to pressure in linen bags, the oil is squeezed out, and the paraffine obtained in an impure condition. The next step of the process is to deprive the paraffine of its smell and colour by the aid of chlorine and chromic acid; it is then washed, redistilled, cooled, and pressed a second time. Finally it is submitted to the action of steam until it is perfectly white and free from odour. It is said that a thousand parts of Irish peat will furnish from ten to twelve of paraffine.

Mr. Young's process is somewhat similar to the last, but he employs Boghead coal in the place of peat. The coal is distilled from a closed retort at a low red heat, and the products are treated in the same way as the last. One hundred parts of Bathgate coal will yield about forty of oil which is fit for lubricating machinery, and ten of paraffine.

Two years ago a patent was obtained by Mr. Brown for the preparation of this substance from bituminous coal and bituminous schist. The process which he adopts is not essentially different from Mr. Young's. The schist is heated in an iron retort, and then exposed to a current of very hot steam. The steam carries over all the volatile matters—namely, the oils, the tar, and the paraffine. These are condensed in a proper receiver; and the semi-solid tar and paraffine are afterwards distilled and then purified by means of sulphuric acid and oxide of manganese, or bichromate of potash. After the residue has been washed with boiling water and weak soda, it is distilled a second time; then cooled, strained, and pressed. The last purification is effected by heating it to a temperature of 400° with strong sulphuric acid. By this means all foreign matters are destroyed; and when washed with boiling water and a solution of soda, it is allowed to set, and is then ready for the market.

Pure paraffine is obtained in the form of brilliant silvery scales when it crystallizes out of boiling alcohol; but the paraffine of commerce is an amorphous substance, having the appearance of a very transparent wax. It is entirely without odour, and it does not communicate a greasy stain to paper. It is slightly flexible, and when warm may be moulded into any shape. It melts at a temperature of 110°, and distils at a red heat, unchanged. Ether, naphtha, the volatile and fixed oils, dissolve it very readily; and it mixes freely with wax, stearine, and the fatty acids. The light emitted from it varies with the size of the wick: when a small plaited wick is used the light is clear, brilliant, and free from smoke; but when the large cotton strands of wax candles are employed, the flame is large, yellow, and very smoky. The experiments which have hitherto been made with this substance, in order to determine its illuminating power, are not sufficiently complete to enable us to judge of its value; but the candles which we have burnt are consumed at the rate of from 166 to 185 grains per hour; and the light emitted has, weight for weight of candle consumed, been exactly one-twelfth less than that of sperm. It is presumed that the price of paraffine candles will be about 2*s.* per pound. At present they are not met with in commerce; but specimens were exhibited in 1852, by Mr. Young, of this country, and by MM. Masse and Tribouillet of France.

LAMP-OILS AND SPIRITS.

Classification.—Oils are divided by chemists into two kinds, namely, *fixed* and *volatile*. The former communicate a permanently greasy stain to paper or cloth, and the latter do not. Olive oil may be mentioned as an example of one, and turpentine of the other. Again, the fixed oils are subdivided into those which become thick or gelatinous on exposure to the air (*drying oils*), as linseed and poppy; and those which do not (*fat oils*), as olive and sperm. The cause of this change will be referred to directly; but it may be remarked, in a general way, that drying oils are not adapted for combustion in lamps, on account of this disposition to become thick and so to clog the wick.

The composition of oils is very much the same as that of the solid fats or butters; they consist, for example, of two or more ingredients, namely, *liquid oleine*, which is always present in very large proportion, as from 70 to 90 per cent., and *solid margarine* or *stearine*. In addition to this, many of the animal oils, as sperm, whale, seal, fish, &c., contain a volatile fat, which gives them their peculiar odour. In the case of whale and seal oils, this is called *phocenine*. The relative proportion of the solid and liquid

constituents of different oils is subject to great variation, and hence the difference in the property of solidifying or becoming thick during cold weather. It must be stated, however, that all oils deposit a solid tallow-like material when they are subjected to cold; and when this deposit is very considerable in amount, as is the case with the oils of cocoa-nut, lard, olive, &c., such oils are not well adapted for burning in lamps unless they are used in rather warm places.

The sources of oils are very extensive; in fact, they are found in both kingdoms of nature. Animals yield to us lard and tallow-oil, sperm, whale, porpoise, seal, walrus, herring, cod, ling, and other such oils; while vegetables furnish us with the oils of almond, olive, rape, colza, cocoa-nut, linseed, hemp, mustard, poppy, cotton, teal, sessama or gingilie, castor, &c. In the former case the oil is obtained either from the cellular tissue which lies immediately beneath the skin, or else from the liver; and in the latter it is procured from the fruit, or the cotyledons of the seeds.

The modes of extraction vary with different circumstances; so much so, that it is scarcely possible to give a general description of the numerous processes adopted. In the case of lard, tallow, and cocoa-nut oils, the solid fats are slightly warmed, then enclosed in linen or horsehair bags and submitted to enormous pressure—a pressure of from four hundred to six hundred tons. The common fish-oils, as those of the herring, pilchard, and sprat, are obtained by piling the fish into heaps or walls, and then weighting them with stones. The oils from the livers of fish, as the cod, skate, ling, &c., are procured by boiling the livers and skimming off the oil, or else by crushing and pressing, or by allowing them to putrefy, so that the tissue may break up and let out the oil. The fat or blubber of different species of whale, porpoise, seal, dolphin, walrus, &c., is subjected to heat in iron vessels, and then submitted to pressure; and, lastly, vegetable oils are procured by first crushing the seeds, then enclosing the bruised mass in bags, and exposing to enormous pressure: this is obtained either by hydraulic power, or by screws, or by wedges driven by heavy stamps. "Linseed, rape-seed, poppy-seed, and other oliferous seeds," as we are informed by Dr. Ure, "were formerly treated for the extraction of their oil by pounding them in wooden mortars with pestles shod with iron, set in motion by cams driven by a shaft, turned with horse or water-power; then the triturated seed was put into woollen bags, which were wrapped up in hair-cloths and squeezed between upright wedges in press-boxes, by the impulsion of vertical rams, driven also by a cam mechanism. In the best mills, upon the old construction, the cakes obtained by this first wedge-pressure were thrown upon the bed of an edge-mill, ground anew, and subjected to a second pressure, aided by heat now as in the first case. These mortars and press-boxes constitute what are called Dutch mills. They are still in very general use, both in this country and on the continent; and are by many persons supposed to be preferable to the hydraulic pressure."

Sometimes the crushed seeds are exposed to the action of heat and a little moisture during the operation of pressing. This facilitates the flow of the oil, and consequently makes the seeds yield a larger produce; but the oil is never so good under these circumstances, as it contains much colouring matter, together with mucilage or vegetable mucus, and sugar; all of which diminish the combustibility of the oil, and render it very liable to become rancid. In the former case the oil is said to be *cold drawn*, and in the latter *hot*. The amount of oil obtained in this manner varies with different seeds, and even with the same seeds in different countries and seasons. Walnuts and hazelnuts usually furnish about half their weight of oil; poppy seeds, nearly half; olives, about one-third; rape-seed, a third; and that variety named colza, about two-fifths;

hemp-seed, a fourth; almonds, a fourth; linseed, from one-fourth to one-fifth; and the seeds of grape, or wine-stones, about one-tenth.

Olives are sometimes allowed to ferment, so as to become soft and pulpy before they are crushed and pressed. In this way they yield a larger proportion of oil, but the oil is not good, and is only fit for lamps or machinery.

We shall take occasion to notice more particularly the details of all these processes when we come to the subject of the individual oils.

Refining or Purifying.—In the state in which oils are first obtained from plants and animals, they always contain impurities, as albumen, vegetable mucus, colouring matter, sugar, rancid acids, &c. These must be removed before the oil is fit for combustion in lamps; and several processes are adopted for this purpose. Sometimes the oil is merely exposed to the action of steam or boiling water; and, after having been well agitated therewith, it is allowed to stand until the oil floats to the surface in a clear or pellucid condition: it is then drawn off by means of a syphon or tap, and so separated from the water which holds the impurities. At other times it is boiled with weak alkaline solutions, or with lime water, and allowed to repose. Dossie's process for purifying fish-oils is as follows:—To each gallon of oil an ounce of powdered chalk, and half an ounce of recently slaked lime, are added: after standing a short time, about half a pint of water is carefully stirred in, and the mixture is agitated at intervals of two or three hours for a period of several days. At the expiration of that time a solution of one ounce of pearlash in four ounces of water is stirred in, and the stirring is kept up at intervals for several hours: after this, two ounces of salt dissolved in a pint of water are poured in, and the mixture is agitated occasionally for the next two days. It is then allowed to stand until it becomes clear; and if the oil is not sufficiently pure and free from odour, the process is to be repeated, taking care that the quantities of the ingredients are reduced one-half.

The plan that is usually adopted for the purification of oils is founded on the fact, that concentrated sulphuric acid, in small quantity, has the power of decomposing the impurities of oil without touching the oil itself: but in carrying out the process, care must be taken that oil of vitriol is not added in too great quantity, or allowed to act for too long a period. The process is generally conducted in the following way:—About one per cent. of commercial sulphuric acid is cautiously added, little by little, to the impure oil; in those cases where the oil clots with strong acid, as happens with linseed oil, the vitriol acid must be diluted with about half its bulk of water before it is added. The mixture is then stirred for several hours, in order that the acid may be brought into contact with all the impurities in the oil; the stirring is generally effected by means of a sort of churn or spindle with cross pieces, which is kept slowly revolving in the vat containing the mixture. In the course of a few minutes after the vitriol is added, the oil becomes discoloured; and after the agitation has been kept up for some time, the impurities clot together in the form of flakes. When this happens the oil is allowed to stand quiet; and in the course of a few hours the flakes subside and leave the oil in a clear and almost colourless condition. The oil is now run off into vats and boiled up with about half its bulk of water; this removes any acid that may be adhering to the oil: the fire is then withdrawn, and in a short time the oil floats upon the water, and may be run off into casks ready for the market.

Other processes have been recommended for the purification of oils; as, for example, the filtration of them through animal or peat charcoal, or the exposure of them to the action of light, or to the chemical influence of a weak solution of chloride of lime; but

all these processes are more or less difficult of management, and consequently they have given place to the more speedy and certain method of refining by means of oil of vitriol. It may, however, be stated that the filtration of oil through charcoal is a very effectual plan for removing bad colour or bad odour.

General Properties of Oil.—Every variety of fixed oil communicates a greasy stain to paper or cloth, and has an unctuous feel. It is also perfectly insoluble in water; and when mixed therewith, speedily rises to the surface. This shows that it is lighter than water; in fact, a bottle which, when full, holds 1000 grains of distilled water, will contain only 884 of sperm oil, or 965 of castor oil. These are the two extremes, for sperm oil is the lightest of all the fixed oils, and castor the heaviest. Chemists have applied the term *specific gravity* to these numbers; and as it is found that each oil has its own particular weight, specific gravity is made the means of discovering the nature and quality of any doubtful oil. The following table represents the relative weights or specific gravities of different fixed oils:—

Sperm	884	Cherry-stone	924
Tallow	900	Fish	924
Rape-seed	913	Cameline	925
Plum-kernel	913	Nightshade	925
Henbane-seed	913	Sunflower-seed	926
Colza	914	Hemp-seed	926
Ground-nut	915	Cocoa-nut	926
Olive	916	Walnut	926
Sessamum	916	Filbert	926
Almond	917	Anda	927
White mustard-seed	918	Horse-chestnut	927
Radish-seed	919	Cod-liver	928
Grape-seed	920	Seal	929
Poppy-seed	922	Linseed (new)	930
Whale (train)	923	Weld-seed	936
Black mustard-seed	923	Orange-seed	940
Walnut	923	Linseed (old)	960
Cucumber-seed	923	Castor	965
Tobacco-seed	923		

Most of the fixed oils are affected by the atmosphere—the oxygen of which they slowly absorb. In some cases the oil becomes thick; or if exposed in a thin layer, it dries. In this manner a skin is frequently formed over the surface of the oil; and if it be left for some time in a lamp, it will assume a jelly-like appearance. Other oils do not become so thick by exposure to the air; but they acquire an unpleasant smell, and get rancid. The former is the property of the drying, and the latter of the fat or unctuous oils. These changes are due to the action of atmospheric oxygen; indeed, Saussure found that a layer of nut-oil, one-fourth of an inch in thickness, absorbed as much as 145 times its bulk of oxygen in the course of eleven months, of which quantity 142 volumes were taken up during three months' exposure to the sun. It appears also that it is the carbon of the oil which undergoes oxidation; and, as it were, slowly burns, evolving carbonic acid. This change is always accompanied with an elevation of temperature; and hence it sometimes happens that rags or tow, or cotton, that have been smeared over with oil and then thrown aside as useless, have, in the course of a few days, generated heat enough to produce spontaneous

combustion. Fires have frequently originated in this manner in warehouses and dockyards, where such materials have been allowed to accumulate. This points to the danger that is attendant on the careless and slovenly trick of throwing greasy rags and other such matters into out-of-the-way corners. Those oils which absorb oxygen with great facility, and thereby become thick, are not well suited for combustion in lamps, unless the lamp is cleaned out every day and a fresh wick adapted to it. The quick-drying oils are linseed, poppy, walnut, hemp-seed, and nut—all of which are employed by painters on this very account; while rape, colza, sessama or gingilie, cocoa-nut, grape-seed, cameline, sunflower, cotton, mustard, &c., only dry after very long exposure to the air; and sperm, olive, almond, seal, and whale oils are not much disposed to dry at all.

Heat and cold act upon the oils and produce changes in them which are more or less hurtful. In cold weather—that is, at a temperature below 32°—most of the oils become thick, from the congelation of their solid constituents; and we then find great difficulty in making the oil burn in a lamp. At a temperature of 600°, or thereabouts, the several fats begin to boil; and if the temperature be carried a little higher, the oil undergoes decomposition, and gives forth a most irritating and unpleasant vapour, which is called *acroline*. At still higher temperatures, the fixed oils are resolved into combustible gases, which burn with a very bright light and a sooty flame: indeed, the object of all the arrangements for the combustion of oil in lamps for illuminating purposes, is that of bringing the oil slowly into contact with the burning wick, so as to generate the gas in question, the supply of which ought to be duly apportioned to that of the air which consumes it. When oils are heated to near their boiling-point, they frequently become thick, and acquire an increased disposition to absorb oxygen. It is on this account that inferior drying oils cannot be employed for any length of time in a lamp, without closing the channels that lead to the wick; and hence it is found necessary to clean the lamp very frequently, or else to pour away the residue of the last consumption before fresh oil is supplied. The same circumstance leads to the stoppage of the pores of the wick, and finally to a total occlusion of all the fine capillary channels by which the oil ascends to the flame; so that a new wick and a clean lamp are indispensable to the perfect combustion of an inferior oil.

Although the fixed oils are not soluble in water, yet they combine very readily with fluids which contain alkaline matters, as soda or potash. In this way they form white emulsions of the nature of soap; and the alkalies, or their carbonates, may be at all times resorted to for the purpose of cleaning out the half-gelatinized oils from old lamps. Ammonia, also, or strong sal volatile, is a very effective agent for removing grease from the clothes.

Concentrated sulphuric acid acts on the fixed oils in the same way as it operates on the solid fats: it first combines with the fatty acids, and then with the basic constituent to form composite acids, named sulpho-oleic, sulpho-margaric, sulpho-steric, and sulpho-glyceric acids. These are not permanent compounds, and have not, therefore, been isolated; but when they are treated with hot water, they are decomposed, and as the sulphuric acid separates, the other fatty constituents resolve themselves into four new acids—namely, metamargaric, hydromargaritic, metoleic, and hydroleic. The first two are solid, crystallizable, and partly volatile, while the last two are liquid and oily. Besides these changes, there are others effected by the action of the sulphuric acid on the sugar, mucilage, colouring matter, &c., contained in the oils; and these are so peculiar and characteristic, that they have been made the means of discovering the nature of a fixed oil. This fact was first recognised by Heidenreich of Strasburg, in

1841; but it has been greatly developed by the investigations of Penot, Marchand, and others. The mode of proceeding is as follows:—Put eight or ten drops of the oil on a white plate, and then let fall into the centre of the oil a single drop of concentrated sulphuric acid: in the course of a few seconds or minutes, the characteristic tints will be observed. Another mode of conducting the experiment is to stir the drop of acid so as to mix it with the oil. The following are the changes observed:—

(*a.*) With *olive oil* there is a yellow colour produced at the points of contact; this rapidly passes into orange, and at last into a bright chestnut-brown, while the surrounding parts of the oil gradually acquire a dirty gray, and finally a smoky tint; but there is never any shade of blue or lilac. If the mixture be stirred, it speedily becomes dirty-brown or brownish-gray.

(*b.*) *Poppy oil* immediately acquires a fine lemon-yellow colour, which soon becomes darker in some parts. The surrounding portion gradually assumes a rose tint, which speedily passes into violet, and then into a violet-blue. This requires a period of from half an hour to three-quarters, and finally the yellow colour becomes dirty-brown. If the oil has been kept for some months, or if it has been expressed by the aid of heat, it will then assume a greenish tint. When stirred it acquires a brownish-olive colour.

(*c.*) *Nut oil* produces almost exactly the same tints as olive oil, but it becomes brown more rapidly, so that within ten minutes it acquires a chestnut-brown colour, and the gray border changes into olive-green. If it be stirred, the oil clots and becomes dirty-brown.

(*d.*) *Castor oil* assumes a yellow tint, which slowly passes into grayish-red, and at last, after many hours, into purple-brown. When the oil is very old it becomes brown at once; and if the oil and acid be stirred, the tint is pale yellow, and then brown.

(*e.*) *Almond oil* produces nearly the same reactions as olive oil; but the surrounding tint is pale grayish, and the yellow has a greenish tint. If stirred it becomes dirty-green.

(*f.*) *Sessama*, *gingilie*, or *teal oil* assumes a yellowish colour, which in the course of a few minutes becomes orange, and then chestnut-brown, the surrounding oil acquiring, in the course of half an hour, a purplish-tint. If it is stirred it acquires an orange-brown colour directly.

(*g.*) *Orange-seed oil* takes on a yellow shade, which rapidly passes into brown, and then into black. If stirred it becomes black almost immediately.

(*h.*) *The oil of black and white mustard-seed* is first yellow, then rich yellow-orange, and finally, in the course of a few minutes, brownish-black, the surrounding oil being of a greenish tint. By stirring, the dark tint is brought out almost immediately.

(*i.*) *Linseed oil* becomes rich chestnut-brown almost immediately, and it soon coagulates, or clots into a hard, tenacious spot. When stirred it immediately thickens, and acquires a brownish-black appearance.

(*k.*) *Hemp-seed oil* presents nearly the same character as linseed, except that this oil assumes a greenish-yellow tint at the edges of the acid; and if stirred it acquires a greenish-brown colour.

(*l.*) *Cocoa-nut oil* acquires a pale purplish-brown colour, which gradually darkens; and when stirred it is first ochre-brown and then deep violet-brown.

(*m.*) *Refined rape-seed oil* assumes the same appearances as the last; and it is charred, as it were, by the acid.

(*n.*) *Fresh-drawn* or *raw rape-seed oil* becomes bright green; and then, after the lapse of ten minutes or a quarter of an hour, the tint deepens, and finally becomes

olive-green or dirty greenish-brown; the surrounding edges retain a bright green colour. If the oil and acid be stirred, the tint is bluish-green, and at last olive-green.

(*o*.) *Oleic acid* changes into a sepia brown, which at length darkens almost to a black.

(*p*.) *Neat's-foot oil* becomes yellow, and then after some time brownish. If stirred, it changes into a dirty-brown at once.

(*q*.) *Whale* or *train oil* acquires a reddish-brown colour, with the edges of a violet tint; and if stirred it passes into dark violet-brown, like that of the lees of wine.

(*r*.) *Cod* and *other liver oil* instantly changes to a rich violet, with the edges of a carmine colour; in the course of a few minutes this passes into orange, and, finally, into dark-brown. When stirred, the violet tint is very remarkable, but very transient.

(*s*.) *Seal oil* assumes a yellow colour, which passes into rich orange and then into blackish-brown, having a number of purple spots about the mixture. When stirred, it acquires a lively yellow tint, which soon changes to orange-brown.

If the acid is diluted with one-third its bulk of water, the reactions are slower, and the effect, in some cases, is more marked. With such a mixture, olive, almond, and castor oils show but little action; while poppy, orange, and mustard become dirty-brown; gingilie, yellowish with a pink border; linseed, brown; rape, green; cocoa-nut and refined rape, pale purple-brown; sessama, lavender; oleic acid, dirty-brown; sperm, pale lavender; cod-liver, rose, passing into rich violet and then into brown; common whale, black-brown; seal, dirty-brown; and tallow-oil, blackish-brown.

Mixtures of the above-mentioned oils give reactions which are compounded of the preceding; and thus the fraud of adulteration may be easily detected.

Another reaction which has been noticed during the admixture of the oil with concentrated sulphuric acid, is that of a great elevation of temperature; and, as each oil produces its own amount of heat, M. Maumené has proposed that this reaction should be used as a means of discovering the quality of an oil. Maumené's results have been confirmed in the laboratory of Professor Fehling by Faisst and Knauss, who state that when 225 grains of oil are quickly mixed in a thin glass vessel with 75 grains of the strongest sulphuric acid, the following are the number of degrees raised by different oils:—

Olive oil . . .	68° Fah.	Rape oil . . .	100° Fah.
Lucca oil . . .	72° ,,	Poppy oil . . .	127° ,,
Almond oil . .	72° ,,		

With an acid of 90 per cent. the rise is:—

Lucca oil .	54° Fah.	Rape oil .	67° Fah.	Linseed oil .	133° Fah.

Mixtures of these oils produce intermediate results.

Aqua-fortis, or *nitric acid*, acts with more or less energy on the fats, and converts them into other acids; one of which, namely, suberic acid, is a very constant product. But the most remarkable change is brought about in all the fats by means of *nitrous acid*, or a solution of *nitrate of mercury*. Either of these compounds will cause the fat oils to become solid; the oleine of the oil being converted into a semi-transparent jelly-like mass, named *elaidine*. This curious change is effected in olive, almond, rape-seed, hazel-nut, and other non-drying oils; but the drying oils, as linseed, hemp-seed, walnut, poppy, &c., are not affected by these compounds. This circumstance, and the facility with which the change is brought about, offer a means of distinguishing one kind of oil from another. M. Poutet recommends the following method for the application of this test:—Dissolve six parts of mercury in seven and a half parts of nitric acid (sp. gr. 1·35); add two parts of this solution to ninety-six parts of oil, and shake the mixture every now

and then for half an hour or so. If the experiment be made on pure olive oil, it will congeal in the course of seventeen hours in summer, or four hours in winter. Other vegetable oils do not combine so quickly with nitrate of mercury; and the mixture either remains fluid, or else the olive oil congeals, and the other oil separates into a distinct layer. If the oil has been adulterated with animal fat, the mixture congeals in five hours, whilst the olive oil floats on the surface and may be decanted. MM. Boudet and Fauré have shown that this change is brought about by the *hyponitrous acid* contained in the nitrate of mercury. They therefore recommend a solution of that acid in aqua-fortis—*common nitrous acid* does very well for the purpose; and they say that each of the fat oils takes its own time to solidify, and develops its own colour. When one part of hyponitrous acid is dissolved in nine of aqua-fortis, and then added to a hundred parts of oil, the colour produced, and the times of solidification, are as follow:—

Olive oil	becomes	greenish-blue,	and	solidifies in	73	minutes.
Almond	,,	dingy-white	,,	,,	160	,,
Filbert	,,	greenish-blue	,,	,,	103	,,
Acorn	,,	lemon-yellow	,,	,,	40	,,
Castor	,,	golden-yellow	,,	,,	603	,,
Colza	,,	yellowish-brown	,,	,,	2400	,,

Oil of poppies retards the solidifying effect, and this to so great an extent, that when present in either of the above, in no larger portion than one per cent., it delays the action for forty minutes.

A mixture of *equal parts of nitric and sulphuric acids* also affects the coloration of the fixed oils; and this has been shown by M. Behrens, as well as by MM. Guibourt and Reveil, to be a good means for detecting the adulteration of oils. About 150 grains of the mixed acids are added to a like quantity of the oil, and the colour, which is instantly produced, is as follows:—

Oil of Sessama . .	dark grass-green.
,, Olive . . .	light yellow.
,, Linseed . .	brownish-red.
,, Almond . .	peach-blossom.
,, Castor . .	little changed.
,, Colza . . .	reddish-brown.
,, Poppy . .	brick-red.
,, Gingilie . .	rich orange-brown.
,, Orange-seed .	rich chestnut-brown.
,, Mustard . .	orange-brown.
,, Rape-seed (raw) .	orange-red and then dirty green.
,, ,, (refined)	yellow-red and then purple-brown.
,, Cocoa-nut . .	pale orange-red.
,, Sperm whale .	orange.
,, Seal . . .	orange-brown.
,, Cod-liver . .	pinkish-violet.
,, Tallow . .	dirty brown.
,, Neat's-foot . .	,, ,,

M. Behrens states that when olive oil is mixed with a fourth part of its weight of sessama oil, it takes a beautiful green colour; but Guibourt and Reveil assert that it will discover one-tenth part of sessama in oil of olive.

Other oxydising agents, as *chromic acid*, or *a saturated solution of bichromate of potash, in oil of vitriol*, also act in a very characteristic manner on the fixed oils. This fact was first observed by M. Penot, who employed a single drop of the latter solution with twenty drops of oil, stirring them together on a white plate. The following are the effects produced:—

Almond oil . .	becomes	yellowish in small lumps.
Hemp-seed oil .	,,	yellow in clots on a green ground.
Rape-seed oil .	,,	,, ,, ,, ,,
Poppy oil .	,,	,, ,, ,, ,,
Ditto (cold-drawn)	,,	,, ,, white ground.
Castor oil . . .	,,	slightly green.
Linseed oil .	,,	brown clots on a white or greenish ground.
Nut oil . .	,,	brown clots.
Olive oil . .	,,	brown.
Cod-liver oil .	,,	dark red.
Whale oil . .	,,	brownish-red clots on brown ground.
Tallow oil . .	,,	reddish-brown.
Neat's-foot oil .	,,	brownish red spots on brown ground.

The illuminating power of different oils varies with different circumstances, as with the temperature of the room, the size and form of the wick, and the freedom with which the oil is supplied to the flame; so that it is difficult to arrive at anything more than an approximation to the value of different oils as illuminating agents. Count Rumford estimated the relative illuminating power of different oils when burnt in Argand and in common lamps, thus—the numbers being the weights consumed to get an equal amount of light:—

Good wax, well-snuffed	100 grains.
Olive oil in an Argand lamp	100 ,,
Olive oil in a common lamp	129 ,,
Rape oil ,, ,, ,, ...	125 ,,
Linseed oil ,, ,, ,, ...	120 ,,

From some experiments which have been conducted for the purpose of arriving at an approximation to the relative value of different oils, we have drawn up the following table, which represents the proportions of oil to be consumed in order to obtain a light of given value—namely, that of thirteen sperm candles, each consuming 120 grains per hour. In these experiments the same lamps were used for each of the oils, and the wick was in each case of precisely the same description; a new wick being employed for each experiment. The consumption of oil in the Argand ranged between 316 and 378 grains per hour, and that of the common lamp between 87 and 123.

	Argand Lamp.	Common Lamp.
Tallow	1008 grains.	1300 grains.
Sperm	1029 ,, ...	1751 ,,
Train	1067 ,, ...	1941 ,,
Olive	1080 ,, ...	2014 ,,
Seal	1107 ,, ...	1892 ,,
Sessama	1113 ,, ...	1776 ,,
Poppy	1119 ,, ...	1660 ,,
Refined rape . . .	1134 ,, ...	1881 ,,

	Argand Lamp.	Common Lamp.
Refined linseed	1231 grains.	2376 grains.
Raw rape	1236 „	1940 „
Brown rape	1343 „	1827 „
Mustard-seed	1354 „	2058 „
Fish	1362 „	1976 „

From this it will appear that there is no direct relation between the illuminating power of the oil and its consumption; for in some cases the oil burns better in the common lamp than it does in the Argand, and *vice versa:* showing that the illuminating power is modified by circumstances. This table has been constructed on the scale of thirteen sperm candles of standard value, because they represent the light of an Argand burner consuming five cubic feet of coal-gas per hour.

VARIETIES OF OILS EMPLOYED FOR ILLUMINATING PURPOSES.

Animal Oils.—(*a.*) *Sperm oil.*—This, as we have already said, is the fluid portion of the head-matter which is removed from the cranial cavity of the spermaceti whale (*Physeter macrocephalus*). The oil is separated from the spermaceti by means of cold and pressure; and after having been purified by means of a little weak sulphuric acid, or alkaline lees and water, it is sent into commerce. Sperm oil is of a pale colour; it has but little odour, and it shows no disposition to congeal in cold weather, or to resinify on exposure to the air; it is, therefore, well suited for illuminating purposes.

(*b.*) *Common whale oil*, or, as it is sometimes termed *whale train-oil*, is derived from several species of whale; as the common whales (*Balænæ*), the finned whales (*Balænopteræ*), and the narwhales (*Monodons*). Most of the oil consumed in this country is furnished by the common Greenland whale, the *Balæna my sticetus*, large numbers of which are annually captured by the whalers of England and America in several of the Arctic Seas. They are taken in the Greenland seas; in Davis' Straits; along the coasts of Spitzbergen, Iceland, and Norway; off Labrador; in the Gulf of St. Lawrence; around Newfoundland; in Baffin's and Hudson's Bays; and in the seas northward of Behring's Straits. The balæna is also found in more congenial climates, as on the coast of Ceylon, and in the China Sea.

In the early days of whaling, when the animal was found in great numbers immediately around the shores of Spitzbergen, the Dutch formed a settlement on that island, and performed there all the operations of preparing the bone and extracting the oil. They gave the name of Smeerenberg (from *smeeren* to melt) to their settlement; and to so flourishing a state did the fishery arrive, that, during the busy season, every species of luxury could be obtained at the village, although it was situated within a few degrees of the pole. This was the condition of things towards the close of the seventeenth century. But it appears from a narrative of the voyage of Ohthere the Dane, given by King Alfred in his translation of Orosius, that the pursuit of the whale was practised by the people of Norway at least as early as the ninth century. We have no account, however, of the way in which the animal was captured, nor are we informed as to the object of the pursuit—whether it was for mere sport, or for some useful purpose. It is very probable the business of hunting the whale was not carried out upon any systematic plan, but was confined to such accidental encounters as opportunity offered. As early as the twelfth century, the inhabitants of the coast surrounding the Bay of Biscay were undoubtedly engaged in the capture of the whale for commercial purposes; and they are generally regarded as the founders of this species of enterprise. At first their

operations were confined entirely to the neighbouring bay; but as the whale became scarce, the Biscayan mariners extended their search farther and farther from their shores, until they reached the coasts of Iceland, Greenland, and Newfoundland. "Thus," says Mr. Dewhurst, "was commenced, in the course of the sixteenth century, the northern whale-fishery, as pursued in modern times. In 1594 the English made their first whaling voyage; and four years afterwards the merchants of Hull fitted out several ships for the purpose: about the same time the Dutch were tempted to engage in the trade; and soon afterwards the Hamburgers, the French, and the Danes were occupied in the same pursuit."

The whale is captured by means of harpoons, and when it is dead it is drawn to the side of the ship and flensed or cut up. This is effected by means of spades and powerful knives, the blubber being cut into cross pieces of about half a ton each, which are hoisted on deck, and then subdivided into small strips, which are forced into the bung-holes of the storing casks. The blubber is the true skin of the animal; and it consists of a net-work of intersecting fibres, which enclose the liquid fat. It encompasses the whole of the body: its thickness varying from eight to twenty inches, though one foot is about the average; and a single whale will yield from twenty to eighty tons of it. The lips of the animal furnish the best kind of blubber; and they weigh from one and a-half to three tons each. The quantity of oil so obtained amounts to about three-fourths of the entire weight of the raw blubber.

Formerly, it was the custom to extract the oil from the blubber at the places where the whales were caught, but now this process is effected after the fat arrives in this country. The operation is thus managed:—The half-putrefied fat is thrown into vats which have a wire grating at the bottom. The tissue is then broken up by pressure, and the oil runs out into a reservoir, which is placed below the vats: that which remains behind is called *finks*. After the oil has settled for two or three days, it is poured off into another vessel and heated to a temperature of 225°. This causes the albuminous matter to coagulate, which, with the other impurities, soon subsides to the bottom of the boiler. The fire is now withdrawn, and water is poured into the vessel, in order that the dregs may be more easily separated from the oil, and may not stick to the bottom of the boiler. After standing for some time, the oil becomes clear, and then it is run off into casks. Another mode of extracting the oil is to boil the blubber with water, and to skim off the oil as it rises. The oil may also be obtained by allowing the blubber to putrefy, and thus to release the fluid fat from the cells in which it is contained. In this manner, by suspending the blubber in bags over casks, the oil gradually drips out, and is collected.

We have already said that the train oil of commerce is chiefly derived from the common Greenland whale (*Balæna mysticetus*); but when this creature is scarce, another species of balæna—namely, the *Balæna Icelandica*, or nord-caper—is sought for; and under certain circumstances the different species of finned whale, as the *Balænoptera gibbar*, *boops*, *rorqual*, &c., and even the *Monodons* or *narwhales*, may be made to yield train-oil. It is not often, however, that the whaler has an opportunity of capturing these creatures; for they are so swift and shy, that there is great difficulty as well as danger in approaching them. Occasionally they are cast ashore on the northern and western coasts of Europe: and then they become a source of great profit from the quantity of oil which they yield. Some idea may be formed of the value of these animals by the following fact:—In the month of August, 1827, a large specimen of the *Balænoptera rorqual* was found floating off the port of Ostend. It was towed into the harbour by some fishermen;

and when cut up, it yielded 40,000 lbs. or 4000 gallons of oil. The specimen measured ninety-five feet in length, and weighed about 240 tons.

Lastly, it may be stated that the several species of *dolphin* furnish abundance of oil. They belong to the whale tribe, and inhabit the seas of all latitudes; for they are found in the Arctic Ocean, the Mediterranean, the Gulf of Messina, the Adriatic, and on the coasts of China: in many of which places there are large establishments for their capture, in consequence of their furnishing an excellent oil for illuminating purposes. To this order of animals belong the common porpoise (*Phocæna vulgaris*), the round-headed porpoise or ca'ing whale (*Phocæna melas*), and the white whale (*Phocæna leucas*); all of which yield oil in considerable quantity. The common porpoise is captured by the inhabitants of the western islands of Scotland, where it abounds; and we are told that about eight gallons of oil are obtained from each individual. The round-headed porpoise is taken in the Shetland Islands, the Orkneys, and in Iceland; and the white whale in several localities on the shores of the North Sea.

The oil obtained from these sources, when properly purified, is very little inferior to sperm oil: it does not clog the wick or congeal in cold weather, and it burns with a clear white flame, which is tolerably free from smell. About 20,000 tons of whale oil and spermaceti are annually imported into this country.

(*c.*) *Seal oil* is procured from several species of phocidæ. The common seal (*Phoca vitulina*) is captured in large numbers on the shores of Newfoundland: indeed, we are informed that during a good year, hundreds of thousands are taken in that locality, for the sake of the oil which they yield. They are also killed on the northern coast of Scotland, in the Orkneys, Zetlands, and on the shores of Greenland. To the inhabitants of the last-named locality the seal is invaluable; for it furnishes them with food, raiment, and oil. The animal is usually captured with spears or harpoons, and sometimes it is shot. As soon as it is dead, the skin is stripped off, and then the fat is removed and boiled down in copper or iron vessels. Seal oil, like the preceding, is not much disposed to thicken; and hence it is well suited for combustion in lamps.

(*d.*) *Walrus oil* is obtained from the morse or sea-cow (*Trichecus Rosmarus*), many of which are annually destroyed at Spitzbergen and elsewhere, for the sake of the skin, oil, and teeth. We do not receive the oil into commerce in this country, and consequently have litte or no opportunity of testing its value; but it appears that its qualities are not inferior to those of the last-mentioned oil.

(*e.*) *Fish oils* are extracted from the bodies and livers of fish. As examples of the former, we may mention the oils obtained from the herring (*Clupea harengus*), pilchard (*Clupea pilchardus*), and sprat (*Clupea sprattus*): all of which are procured by submitting the fish to great pressure at the time that they are undergoing the process of salting. Of the latter may be mentioned the oils of cod (*Morrhua vulgaris*), ling (*Gadus molva*), skate (*Raia batis, &c.*), burbot (*Lota vulgaris*), torsk (*Brosmius vulgaris*) &c. The oil is obtained by placing the livers in a tub which has a perforated bottom covered with small branches of trees. As the livers putrefy, the oil drips out, and is caught in a vessel placed underneath. At other times the oil is extracted by boiling the livers in an iron pot, and then squeezing them in linen bags. Cod-liver oil is not much used for purposes of illumination, as it is a valuable remedy for the cure of many diseases; but the oil of ling is extensively prepared by the poor of the Orkneys and western islands of Scotland, where it is employed as a common lamp-oil. All these oils are somewhat of a drying nature, and therefore become thick after a time; besides which, unless great care

has been taken in their preparation, they are sure to have a most unpleasant fishy or putrid odour.

(*f.*) *Lard oil, and the oleine from tallow and other animal fats*, is obtained from the solid fats by slightly warming them and then submitting to pressure. This oil is apt to deposit solid matter in cold weather, and thus to become thick; but the properties of the oil are otherwise very good; and consequently it is well suited for combustion in lamps. The *oleic acid*, which is procured during the manufacture of stearic and margaric acids for candles, is not fit for illuminating purposes; for although it gives out a very good light during its combustion, yet it is so apt to clog the wick from the impurities which it contains, that in the course of a very short time the lamp ceases to burn. Were it not for this, oleic acid might be extensively employed as an illuminating agent.

Vegetable Oils.—(*a.*) *Olive oil.*—This is furnished by the fruit of *Olea Europæa*, of which there are two varieties—namely, the *longifolia* of France and Italy, and the *latifolia* of Spain. The olives are gathered as soon as they are ripe, and this takes place early in November. In France, where the best oil is prepared, the fruit is bruised in a mill directly it is gathered; it is then wrapped in a sort of matting and submitted to pressure. The oil which runs out is called virgin oil, and is kept separate for table and dietetical purposes. The cake is removed from the press, broken up by hand, moistened with boiling-water, and re-pressed; in this manner a second quality of oil is obtained, which on standing, separates from the water with which it is mixed. The cake that is left from this operation is called *grignon*, and generally it is set aside to dry in order that it may be used for fuel; but sometimes it is submitted to fermentation, then wetted with boiling-water and pressed a third time, by which means a third quality of oil, called *gorgon*, is procured, which is used for lamps and machinery.

In Spain the olives are allowed to ferment for a period of ten days or a fortnight before they are crushed and pressed. In this way a larger supply of oil is obtained, but the quality is very inferior to that prepared from the fresh nut. One of the reasons why this delay takes place, is, that there are not sufficient presses in the oil districts to perform the necessary work; and hence the several growers are obliged to wait their turn, and keep their olives ready for the mills. But within the last few years considerable improvement has been effected in this respect by the introduction of hydraulic presses; and now a large portion of the oil obtained from Spain is equal, or nearly equal, in quality to that of France and Italy.

The machinery employed by the Neapolitan peasants in the preparation of Gallipoli oil, is of the rudest kind. The olives are allowed to ripen to the fullest extent on the trees; and as they fall off they are collected by women and children, and carried to the mill. The oil which is expressed is put into sheep or goat-skin bags, and conveyed on the backs of mules to Gallipoli, where it is allowed to clarify by standing in cisterns which are cut out of the rock on which the town is built. When it has become sufficiently clear by the deposition of mucilage, water, and other impurities, it is run off into skins, and conveyed to oil-basins which are situated near to the sea-shore. From these it is put into casks, and exported.

According to Sieuve, olives furnish about thirty-two per cent. of oil—twenty-one of which come from the pulp (or pericarp) of the fruit, four from the seed, and seven from the woody matter.

In whatever way the oil is obtained, it must be clarified and freed from mucilage, &c., before it is fit for use. This is usually accomplished by allowing the oil to stand in a warm place for a fortnight or three weeks, during which time it deposits impurities,

and becomes clear. It may also be refined by heating it for a short time with a weak solution of potash or soda, and then allowing it to stand; or it may be deprived of its acid congealable matter, by exposing it for some time to the action of a piece of lead—the bottle containing the oil and the lead being placed in a window, or other place where it will receive the direct rays of the sun. In this way the oil used by watchmakers and machinists is refined.

The amount of olive oil annually imported into England is about eighteen or twenty thousand tons. In the year 1849, it amounted to 16,864 tons—of which 9,661 tons came from Naples and Sicily (Gallipoli oil); 2,237 from Malta; 1,712 from Turkey; 832 from Tuscany; 753 from Spain; 506 from the Ionian Islands; 368 from Morocco; 333 from Sardinia; and 462 from France and elsewhere. The imports into Liverpool during the year following were 4,815 tons from Gallipoli; 2,330 from Barbary; 2,100 from the Levant; 762 from Corfu; 15 from Leghorn; and 8 from Palermo. The best variety of olive oil is called Florence oil, which is the produce of Aix, in France; while the worst is the Spanish.

In this country the price of olive oil renders it too costly for lamps; but in Italy, Spain, and France, it is extensively employed for such purpose. It burns with a clear white light, and does not emit any unpleasant odour; besides which, it is not a drying oil, and is therefore not likely to clog the wick. When it is adulterated with poppy, nut, or sessama oils, its properties are very much deteriorated.

(*b.*) *Almond oil* is extracted from the kernels of the common almond (*amygdalus communis*), of which, as in the case of the olive, there are two varieties; namely, the sweet (*dulcis*) and bitter (*amara*), both of which yield the oil of commerce. The almonds are agitated in bags, so as to separate a portion of their brown skin, then crushed in a mill, and, after being folded in canvas-bags, they are subjected to pressure between cast-iron plates. That which runs over first is the best. The residue is then heated and again pressed, by which means an oil of inferior quality is procured. When first obtained, the oil is thick and discoloured; but by repose in a warm place, or by filtration through paper or sand, it becomes clear. Almonds yield from twenty-two to twenty-four per cent. of oil. It is too expensive for lamps, though its flame is very brilliant, and its other qualities are remarkably good.

(*c.*) *Rape oil* is extracted from the seeds of several species of brassica (the cabbage and turnip tribe), as the *Brassica oleracea*, *campestris*, *napus*, &c.; all of which are cultivated in this and other countries for the oil which they yield. In France a very superior rape oil, termed *colza oil*, is obtained from a variety of *Brassica campestris*, named *oleifera*. In every case the oil is procured by crushing or grinding, and pressing the seed in the way already described, and it is refined by the addition of one or two per cent. of sulphuric acid. The seeds yield from twenty-eight to thirty per cent. of oil.

Most of the rape oil employed in this country is expressed here. Occasionally we receive small shipments of the oil from Belgium, France, and the East Indies; but by far the larger proportion is obtained from the seed itself, of which we import large quantities. In the year 1850 we received as much as 29,490 quarters of the seed from different places: of these, 13,126 came from the East Indies; 3,235 from Russia; 3,092 from Denmark; 2,872 from the Hanse Towns; 2,480 from Austria; 1,637 from Greece; 1,280 from Wallachia and Moldavia; 645 from Prussia; 201 from Holland; and 922 from France and other places. Mr. Brotherton, who is a large oil-presser, states, that good English-grown rape yields the best kind of oil; and he recommends

this fact to the notice of agriculturists, saying that as much as five quarters of seed, worth fifty shillings a quarter, may be obtained from an acre of land.

Rape oil is extensively used for illuminating purposes, both here and on the continent: in fact, it is now the usual lamp-oil of commerce. Its properties are but little inferior to those of sperm; and the only objection that can be urged against it is, that after it has once been heated in the lamp it is apt to thicken and to clog the wick. Colza oil is generally consumed in the Carcel or French lamp; but it has no very great advantages over the commoner kinds of rape oil. The crude or raw oil is not suited for such purposes, on account of the mucilage which it contains: it is of a greenish-brown colour, and has somewhat the odour of linseed oil; but when it is refined it loses both of these objectionable properties, and becomes as pale and limpid as sperm.

(*d.*) *Cocoa-nut oil* is the produce of the *Cocos nucifera*, or common cocoa-nut palm; the fruit of which is decorticated, crushed, heated, and pressed. We have already stated that the oil is imported into this country in a buttery or tallow-like condition; and that after submitting it to pressure between warm plates, the liquid oil runs out, leaving the cocinine or cocoa-nut stearine for the manufacture of candles. The elaine or oleine of *palm oil* may be obtained in a similar way; and both of the oils may be purified by means of common sulphuric acid. Cocoa-nut oil has rather a pleasant odour, and it burns exceedingly well in lamps, provided it is not exposed to too low a temperature; for it is apt to congeal by cold.

(*e.*) *Sessamum or Gingilie oil* is procured from the *Sessamum orientale*, of which there are several varieties cultivated in India for the oil which they yield. These are the *suffed-til* or white-seeded variety; the *kala-til* or party-coloured; and the *tillee* or black. It is from the latter that the oil is chiefly obtained. A large quantity of the oil and seed is imported into this country, and into France for the purpose of adulterating other oils; but in India it is used very extensively as an article of diet, and also for lamps. The oil is extracted and refined in the usual way.

(*f.*) *Ground-nut oil* is obtained in large quantity from the ground-nut or seed of the Bhoe moong (*Arachis hypogæa*), a plant that is pretty extensively cultivated in various parts of India. The seeds furnish about forty-four per cent. of a clear pale-yellow oil, which is largely used as food and for lamps. Two varieties of the plant are cultivated in Malacca,—namely, the white seed and the brown, both of which yield a very good oil. About eighty or ninety tons of this oil are imported into this country every year.

(*g.*) *Common nut oil* is derived from two sources—namely, the *Corylus avellana*, or common hazel-nut; and the *Juglans regia*, or common walnut. The former produces about half its weight of oil, and the latter about one-third. The oil is not much used for lamps on account of its energetic drying properties: indeed, it is more apt to resinify and clog the wick than linseed; but it is largely employed for adulterating other oils.

(*h.*) *Poppy oil* is procured from the seeds of several species of poppy, as *Papaver somniferum, bracteatum, orientale*, &c. The plant that yields the largest amount of oil, and which is usually cultivated for this material, is a variety of the *somniferum*, named *nigrum*, from the black colour of the seeds. Large quantities of this oil are expressed every year for the purpose of adulterating other oils. It is clear, sweet, limpid, and almost colourless; but the great objection to its use as a lamp-oil, is its disposition to dry.

(*i.*) *Linseed oil* is extracted from the seeds of the flax plant (*Linum usitatissimum*), which yield from twenty-two to twenty-seven per cent. of oil. If the seeds be crushed

and pressed at an ordinary temperature, they yield not more than eighteen or twenty per cent.; but the oil is of a pale colour, and is thought by some to be of superior quality to the hot-drawn. A large quantity of linseed is cultivated in this country, but the great bulk of the seed used by the oil-presser is imported. In the year 1850, as much as 626,495 quarters were received here; and of these 482,818 came from Russia; 87,273 from Prussia; 26,142 from the East Indies; 17,517 from Egypt; 7,734 from Holland; 1,476 from Naples; 1,153 from the Hanse Towns; 910 from Wallachia and Moldavia; 870 from Sweden; 268 from Norway; 40 from Austria; 37 from Denmark; and 262 from other places. The seed is crushed, ground, and pressed in the usual way; and the oil is refined by means of dilute sulphuric acid. Linseed oil is not usually burnt in lamps, on account of its drying properties; but if the wick be changed every day, and no more oil is placed in the lamp than is necessary for one night's consumption, it will be found to burn very well, and to give a very clear light. By boiling or heating, it acquires increased consistence, and is then more apt to dry.

(*k.*) *Hemp-seed oil.*—This oil is produced from the Indian hemp (*Cannabis sativa*), the seeds of which yield about one-third their weight of oil. The oil has a disagreeable smell, and is not much employed for illuminating purposes, except by the poorer classes of India.

(*l.*) *Cameline or Dodder oil* is extracted from the seeds of the *Camelina sativa*, a plant that grows abundantly in Canada, where the oil is used as a common lamp-oil. It is also employed for the same purpose in several parts of Germany.

(*m.*) *Cotton-seed oil* is thought to be as good as rape for lighting purposes: indeed, small quantities of the oil have been expressed for several years past and used in this way; but the value of the material has not been fully realized until within the last year or two. At the Exhibition of 1851, specimens of the oil and cake were shown by Mr. Burn of Edinburgh, and by M. De Géminy of Marseilles, to both of whom prize-medals were awarded. It appears that as early as 1785 the importance of this material was perceived by the Society for the Encouragement of Arts and Commerce, for they offered a prize for its manufacture on a large scale; but it does not seem to have been taken up extensively, perhaps because of the difficulty in purifying the oil. It has, however, been extracted for some time in India, America, and Egypt. Of late years the oil has attracted attention, and means have been devised for its purification. This is of interest, because very large quantities of cotton-seed are destroyed every year: in fact, more seed is always produced than is required for the next year's crop, and hitherto this excess has been thrown away as useless. At present it is exported to this country or to France, where it is crushed and pressed. Mr. Burn of Edinburgh, and M. De Géminy of Marseilles, have each large mills for the expression and purification of the oil. When first expressed it has a dirty-brown colour; but by rectification with sulphuric acid, it becomes clear, and assumes a pale amber tint, in which condition it is well suited for combustion in lamps. The botanical name of the plant which furnishes the seed is *Gossypium herbaceum*. It is cultivated in India, Syria, Asia Minor, along the Mediterranean, and in America.

(*n.*) *Mustard Oil.*—This is procured from the dross or siftings of black and white mustard-seed (*Sinapis alba* and *Sinapis nigra*), both of which are cultivated very extensively in this and other countries, for the manufacture of mustard-flour. The siftings furnish about forty per cent. of a dark-brown oil; the seeds themselves yield from eighteen to thirty-six per cent. In India an excellent oil, called *shersha*, is expressed from several species of *sinapis*, as the *toria*, *glauca*, *nigra*, &c. All these varieties of

mustard oil are very dark-coloured when first expressed, and they have the peculiar pungent odour of mustard. Both of these properties are, however, removed by the process of refining; and then the oil may be used in the place of rape or colza for illuminating purposes. Usually the oil is employed for the adulteration of the latter.

(*o.*) Besides these oils, many others are employed in various parts of the world for the purpose of giving light; thus, the oil of plum-stones (*Prunus domestica*) and of raisin-stones, or wine-stones (*Vitis vinifera*), are used in Spain, Germany, and France. The oils of belladonna-seed (*Atropa belladonna*), tobacco-seed (*Nicotiana tabacum et rusticum*), and henbane-seed (*Hyosciamus niger*), are used in Swabia and Wurtemburg. Oils are also extracted from the beech-nut (*Fagus sylvatica*), sunflower-seed (*Helianthus annuus*), weld-seed (*Reseda luteola*), orange-seed (*Citrus aurantium*), cucumber-seed (*Cucurbita pepo*), &c.; and in India there are numerous plants which yield abundance of oil that is well suited for illuminating purposes. Among these may be mentioned *ramtil oil*, or, as it is sometimes named, *teel oil*, from several varieties of *Gurzotia*, as *Gurzotia oleifera* and *Abyssinica*, both of which yield about eighty-four per cent. of oil that is very similar to sessamum oil; *Poon-seed oil*, or *Pinnacottay oil*, from the seeds of *Calophyllum inophyllum*, which furnish about sixty per cent. of it; *Napala oil*, from the seeds of *Jatropha curcas; Mulu unnay oil*, from the seeds of *Argemone Mexicana; Cheeroojee oil*, from the fruit of *Chirongia sapida*, or *Buchanania latifolia;* oil of *Kossumba*, or *Koosm oil*, from the seeds of the safflower (*Carthamus tinctorius*), which yield about twenty-eight per cent. of it; *Kanagu nune*, or *Kurrunj oil*, from the seeds of *Pongamia glabra*, or *Galedupa arborea; Mooncela oil*, from the seeds of *Dolichos biflorus*(?); *Caju apple oil*, from the seeds of *Anacardium occidentale; Lambolee oil*, from the seeds of *Bergera koenigii; common jungle oil*, from the seeds of *Ricinus communis;* and several other varieties, the sources of which are not well known. Many of these oils are admirably well suited for combustion in lamps; and if there were a sufficient demand for them, they might be furnished to commerce in considerable quantity. "The knowledge of this circumstance," say the jurors, in their report on the products of the Great Exhibition, "is of great practical value, because, not only is it possible that by the introduction of improved machinery, or by increased facilities of conveyance, their price may be reduced; but the very existence of such substances tends to equalize the market value of those oils now generally employed. And should, at any time, accidental circumstances cause the price of the latter to advance, these substances would then be most advantageously introduced, and would, probably, ere long, altogether supersede the oils in the place of which they had been originally imported."

Volatile Oils.—(*a.*) *Oil of turpentine or camphine* may be obtained from the oleo-resinous exudation of various species of pine, larch, &c., as the Scotch fir (*Pinus sylvestris*), the cluster pine of Bordeaux (*Pinus pinaster*), the swamp pine of America (*Pinus palustris*), the frankincense pine of Virginia (*Pinus tæda*), the silver fir of Germany, Siberia, and Switzerland (*Abies picea*), the common larch of the Continent (*Larix Europæa*), and the turpentine pistacia of Syria and Greece (*Pistacia terebinthus*). The oleo-resin is imported into this country under the names of common turpentine, Bordeaux turpentine, Strasburg turpentine, and Venice turpentine. The first of these yields the great bulk of the turpentine of commerce; it is the produce of the *Pinus palustris*, and perhaps also of the *Pinus tæda*. It is chiefly imported from the United States of America; from which locality, in 1849, we received as much as 412,000 cwts. The method which is generally adopted for procuring this oleo-resin is as follows:—The tree is selected, and a hollow is cut into it, a few inches from the ground; the bark

is then removed for a space of eighteen or twenty inches above the hollow; and for several months—namely, from March to October—the turpentine flows from the divided sap-vessels into the excavation. At convenient times the semi-fluid matter is scooped out, and put into casks; and when these are full, they are sent away for exportation.

Volatile oil of turpentine is procured from the oleo-resin by distilling the latter with a due proportion of water. The turpentine and water come over together, forming a milky liquor, which on standing, separates into two layers, of which the turpentine is the uppermost. These are easily decanted or poured off one from the other; that which remains in the still is resin. Common American turpentine yields from fourteen to sixteen per cent. of spirits.

The turpentine which is thus obtained is not sufficiently pure for combustion in the camphine lamp, for it contains a small proportion of resin, which is very apt to clog the wick. This impurity is very easily removed by a second distillation, and the product which is thus obtained is sent into commerce under the name of *camphine.* It is a colourless, limpid, and very inflammable liquid, that burns with a remarkably sooty flame. Its specific gravity is 870, and it boils at a temperature of 314° Fah.; though, if water be present, it will distil at as low a temperature as 212°. Turpentine freely absorbs oxygen from the air, and is converted into an oleo-resin. In the course of four months it will take in about twenty times its bulk of atmospheric oxygen. The change which is thus produced in the liquid renders it unfit for combustion in the camphine lamp, in consequence of the resinous oxide having a tendency to clog the wick. To remedy this evil, the liquid must be re-distilled, and the camphine should be preserved in well-corked vessels.

The light that is emitted from turpentine when it is properly burnt is remarkably vivid and white; in fact, the illuminating power of camphine is nearly twice as great as that of sperm oil; and if it were not for the liability of the combustible to evolve smoke, it would be one of the most valuable of modern illuminating agents. This, indeed, is the great objection to its use; for it is found that ever so little mismanagement of the flame causes the production of a cloud of blacks, which settle upon the furniture and dress, and damage them irreparably. To obviate this as far as possible, the chimney of the camphine lamp is made very tall, and thus a strong current of atmospheric air is secured to the flame.

A mixture of turpentine and alcohol has been used in France for some time past, under the name of "*Eclairage au Gaz Liquide.*" The lamp which is employed for the combustion of this material was originally contrived by Lüdersdorff; it is called a vapour-lamp, because it is constructed so as to convert the volatile liquid into vapour, which burns as it escapes through a number of fine orifices. By diluting the turpentine with alcohol, its liability to smoke is considerably diminished; but still there is a large quantity of soot evolved when the mixture is burnt in an open lamp without a glass. The French liquid has a very peculiar odour· it is clear and limpid like water, and has a density of 823. Its boiling point is 190° Fah. When mixed with water, it becomes turbid and milky from the separation of the turpentine, which soon floats to the surface and forms an oily layer, the bulk of which is about half that of the original liquid. From this it would appear that it consists of about equal parts of strong alcohol and turpentine, the mixture being doubtless effected by distilling the two liquids together; for if alcohol and turpentine are merely shaken up together, they will not unite in this proportion: indeed, 100 parts of spirits of wine, of specific gravity 840, will

only take up 13½ of turpentine; and alcohol of much less density (830) will not take up more than 20 per cent. of it.

When the French liquid is burnt in an ordinary open lamp, at the rate of 138 grains per hour, it gives a light which is about two-thirds as great as that of a standard sperm candle.

The great objection to the use of this liquid is its liability to explode when its vapour becomes mixed with atmospheric air. In consequence of this property, the greatest caution is necessary in manipulating with the fluid; for should an explosion take place, the most dangerous results might follow. We are not likely to employ the mixture in this country, on account of the high price of spirits of wine; but in France and Germany, where alcohol is comparatively cheap, the fluid is often used as an illuminating agent at railway stations in country towns.

(*b.*) *Coal-naphtha.*—When coal is distilled for the manufacture of gas, a tar is obtained which is the source of common naphtha. The tar itself is a very complex material, for it contains a number of oily acids, alkalies, and neutral bodies. As it comes from the gas-works it is a thick, dark liquid, of a most offensive odour. To extract from it its various constituents, it is put into large iron retorts or stills, and submitted to distillation; that which comes over first is of an aqueous nature, and smells strongly of ammonia; then follows a brownish oil, which floats on the preceding. After a time, a denser or heavier oil begins to makes its appearance; and when this happens the receiver is changed, and the first product is set aside for the manufacture of light oil or crude naphtha. The coal-tar generally yields from four to five per cent. of this fluid. As the distillation of the tar proceeds, a heavy oil, which falls to the bottom of water, and is hence termed dead oil, comes over. This is used, under the name of creosote, for the preservation of timber. After this a yellowish semi-crystalline fat, called naphthaline, makes its appearance; and, finally, a more solid material, named paranaphthaline, distils over. That which remains in the retort is pitch.

The crude coal-naphtha is rectified either by distilling it a second time, or by driving steam through it and collecting the condensed products. In this way it is separated from another portion of heavy oil which remains in the still.

The light naphtha thus obtained is sent into commerce, and sold for about 2*s.* 4*d.* per gallon, for combustion in the common vapour-lamps which are so frequently to be seen in the streets of London, lighting up the stalls of the poor tradesmen. In this condition it is an amber-coloured liquid, of a powerful gas-like odour and spirituous appearance. It has a density of from 860 to 900—usually it is about 887. It floats on water, like turpentine, and becomes darker coloured by exposure to the air. It mixes very freely with wood-spirit or with spirits of wine; and may thus be burnt like the last-named liquid, in an ordinary lamp.

The light naphtha is further purified for commerce by agitating it with a little oil of vitriol, then washing with water, and redistilling. In this condition it is sold as rectified naphtha. It fetches about 4*s.* per gallon, and is used for combustion in the naphtha spirit-lamps which have a flat wick and oval glass.

Mr. Mansfield has shown that light coal-naphtha contains a number of volatile oils, which may be separated from it by fractional distillation. One of these—namely, benzole—is of great importance. It is procured by boiling the naphtha in a retort to which there is adapted a worm which coils through a vessel of boiling water; the worm is so constructed that all the vapour which condenses in it shall run back again into the still, while the uncondensed vapour (that of benzole) passes on into another receiver,

where it is cooled and collected. The benzole thus obtained is rectified a second time in a similar apparatus, the temperature of the worm being kept at about 176° Fah. In this way a large proportion of volatile oil is obtained, which is further purified by agitating it with one-fourth its bulk of strong sulphuric acid, or, better still, with about one-tenth of strong nitric acid; and then, after separating the nitric acid, it is agitated with oil of vitriol as before. The naphtha is now to be decanted and distilled a third time. If it be repuired to have the benzole perfectly pure, it is submitted to a cold of 4° Fah. This is produced by mixing salt and snow together. The benzole freezes and leaves its impurities in a fluid condition, from which it may be separated by means of a filter.

The use of sulphuric acid in this process is to remove all the basic substances, and to oxydize the brown colouring matter of the naphtha; the nitric acid assists the oxydation, and at the same time forms a small quantity of nitro-benzole, which gives a fragrant, almond-like odour to the product.

Benzole is a limpid, colourless liquid, of a rather ethereal odour; its density is 850—consequently it floats on water. It boils at a temperature of 177° Fah., and gives off a vapour which is very inflammable, burning with a sooty flame. It solidifies at the freezing-point of water, and then looks like camphor. So volatile and combustible is the liquid, that when a current of hydrogen gas is passed through the fluid, or through a sponge moistened with it, the gas will burn with an intensely white light. Atmospheric air charged with the vapour also burns with a smoky flame and a bright light: the flame is sometimes of a violet-blue colour when the apertures of the jet are very small.

Benzole mixes freely with alcohol or with wood-spirit, and the compound so formed burns in common lamps with a very powerful light. It is necessary that the mixture should be made with proper proportions, or else the light of the flame is not good; for if there be too much spirit the light is blue, and if too little it is smoky. The mixture which is found to give the best results, is about one part benzole and two of spirit, of specific gravity 840. This mixture, when burning at the rate of 160 grains an hour, gives a light of from one and a half to two sperm candles.

The extreme volatility of benzole gives to coal-naphtha the property of naphthalizing air or bad gas; for if a little of the liquid be placed in the gas-meter, or in a chamber containing some pieces of sponge through which the gas passes, it will acquire increased illuminating powers. Mr. Lowe, of the Chartered Gas Company of London, has taken out a patent for this mode of naphthalizing gas. Beale's lamp is also a contrivance for naphthalizing atmospheric air. It consists of a cup of naphtha through which a stream of air is made to pass; and to facilitate the volatilization of the naphtha, a hot cap is placed over the cup, so as to communicate its heat to the air and liquid. The other constituents of coal-naphtha are not so volatile as benzole, and hence they are not fit for the purpose of naphthalizing. Mansfield states that the oil which distils over from the crude naphtha at a temperature of 230°, will take fire at its surface, but it yields so little vapour to cold air that the latter, when passed through it, burns with but a feeble blue flame; and the oil which distils at a temperature of 300° is still less inflammable, for it will not take fire at the surface, or furnish any combustible vapour to atmospheric air. In these respects it resembles turpentine, which requires a heat of 311° Fah. to boil it.

A fluid like coal-naphtha is also obtained from the distillation of certain oily matters, or petroleums, which exude from the earth. In many places in the neighbourhood of the Caspian Sea, in Ava, at the Tegernsee in Bavaria, at Amiano in Italy, at Neufchatel, at Saint Zibio in the Grand Duchy of Modena, at Clermont and Gabian in France, at Val di Noto in Sicily, at Rangoon, Barbadoes, Trinidad, Lake Geneka in New York, and many

other places, an oily matter called rock-oil oozes out of the ground, and is collected in pits dug in the earth to receive it. When distilled, it furnishes a volatile oil called naphtha, of which Persian naphtha may be taken as a good example. It is colourless, limpid, very combustible, and burns with a sooty flame. In some places it is used for illuminating purposes.

(c.) *The Oil of Fermented Liquor, Oil of Grain, or Fusel-oil.*—In the process of fermentation, all saccharine fluids produce a volatile oil, which can be separated from the spirit by distillation. Pellitan, in 1825, first noticed this fact; and as he obtained the oil from spirit of potatoes, he called it potato-spirit oil. It was subsequently examined by Dumas (1834); and in 1839 it was investigated by Cahours. More recently Buchner obtained it from corn-spirit. For a long time it was obtained as a waste product by Mr. Bowerbank, a rectifier of London, who used it in his manufactory as an illuminating agent. The oil is procured at the end of the process for rectifying spirit. In its raw and impure condition it is usually called *faints*. It has the odour of bad whisky, and contains alcohol, and various fatty acids. By washing with water, then distilling with carbonate of potash, and, finally, with chloride of calcium, it is obtained in a tolerably pure condition. Five hundred gallons of corn-spirit yield about one gallon of oil. In its pure state, the oil has a peculiar ethereal odour, which, when inhaled, is rather unpleasant and irritating to the throat. Its specific gravity varies from 823 to 840; it boils at 268°, and emits a combustible vapour. The oil is not soluble in water, but it mixes with alcohol and wood-spirit in all proportions. It burns in an ordinary open lamp, with a clear and smokeless flame—the light of which is tolerably intense. A lamp that consumed the oil at the rate of 278 grains per hour, gave a light that was about half as good again as that of a standard sperm-candle. At present the oil is in demand for the manufacture of artificial essences, and consequently it is too expensive for combustion in lamps.

LAMPS.

History and General Principles of the Subject.—It has been already stated that the employment of lamps can be dated back to a very early period; indeed, it is generally thought that they were invented by the Egyptians, who not only used them for common illuminating purposes, but also placed them in the tombs of the dead as emblems of mortality. The ancient Greeks were likewise accustomed to the use of lamps, which we have every reason to believe were fed with a vegetable oil. Herodotus alludes to this fact; and it is further evidenced in many devices that we find sculptured in some of the most ancient Greek vases; but it was centuries after that before the Romans began to employ lamps, and then they were only used in the houses of the rich, or upon occasions of special festivity. That most of the classical nations have been accustomed to place lamps in the sepulchres of the dead is an instructive fact; for, although various motives have been assigned for the custom, there can be no doubt that it was intimately connected with their belief in the existence of a soul, and that it was meant to typify the departure of the spirit or vital fire from its frail tenement of clay. This is clearly set forth in many of the beautiful devices which adorn the funereal lamps of the early Greeks, where the immortality of the soul and its departure from the body is represented by the escape of a butterfly from an apparently dead chrysalis. The testimony of Pliny, St. Augustine, and others, has induced a belief that in many

cases the sepulchral lamps were constructed so as to burn for ever; and some remarkable instances have been cited in which the lamps were said to have been found burning centuries after the tomb had been closed up; but none of these are sufficiently well authenticated, notwithstanding that Liceto and other authors have taken great pains to establish their truthfulness.

It is very probable that the earliest lamps were not made of any set form, but that the fat or oil was placed in any convenient vessel, and fired by means of a bundle of rushes or dried moss. As civilization advanced, and the necessity for artificial light increased, attention would naturally be directed to the form best suited to the wants of the people; and it is very likely that at first the lamp was nothing more than a circular vessel or saucer containing the combustible material. Lamps of this description are still employed on the Continent for purposes of general illumination. It is thought by some persons that the lamps of the virgins alluded to in the Gospel of St. Matthew (chap. xxv.) were merely rods of porcelain or iron covered with cloth, and steeped in oil or fat, and that the same kind of lamp or torch was used by the soldiers of Gideon; but we have no positive testimony in support of such an opinion, although there is plenty of evidence to show that lamps trimmed with oil were in use long before that time.

The next improvement in the form and construction of the lamp is to be seen in the ancient lamps of Herculaneum and Pompeii. Examples of these are to be found at the

Fig. 6.

Fig. 7.

Louvre, the British Museum, the Vatican, and, indeed, in almost every considerable museum in Europe; but the finest specimens belong to the King of Naples, who has a collection of such things at Portici; in fact, in the sixth hall of that museum there is a large collection of lamps taken from the buried cities of Pompeii and Herculaneum. Besides which, Liceto, Bartoli, and Passeri have published descriptions and drawings of many hundreds of such lamps that were in the museums of Italy during the sixteenth century. The common form of all of them is that of an elongated vessel, like a boat, having the wick at one end (Figs. 6, 7, and 8); at other times it was a simple disc, with a hole for the wick on one or both sides, and an aperture in the centre for supplying the oil (Fig. 9). Lamps of the former description are still used by the poor of the Orkney and Shetland Isles.

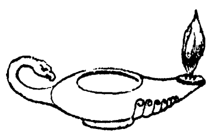

Fig. 8.

The material of which the Greek and Roman lamps were composed was chiefly *terra-cotta*, though some of the better sort were made of bronze, and even of silver and

gold. A few ancient lamps of iron have also been discovered, but they are comparatively rare, perhaps because of the perishable nature of the metal. In the museum at Portici there are several iron lamps, together with one of glass, all of which were taken from the ruins of Herculaneum.

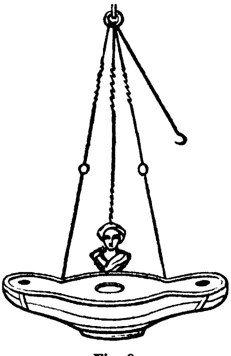

Fig. 9.

Much ingenuity was exhibited by the Greeks and Romans in the construction and ornamentation of the supports (the λυκνουκοι, *lampadaria* or *candelabra*) which held the lamps. At first these were composed of cane, and the Greeks in all their designs never lost sight of this fact; consequently we find a variety of vegetable forms blended with the stiff reed, giving it lightness and elegance: the twining ivy and the graceful acanthus were frequently associated in this manner. With the Romans, however, the usual support was a tripod resting on lions' feet.

At a very early period it must have been observed, that when an attempt was made to enlarge the wick beyond a certain point, the flame became dull and smoky. To remedy this, it was customary to split the wick up with a number of small flames, each of which would allow the atmosphere to play freely around it, and thus to keep up a tolerably good combustion. There is no doubt that this device was well known to the ancients (Fig. 8), though it is generally considered that Dr. Franklin was the first to show that the same quantity of cotton divided into two wicks gives a better light than when it is used as one; but the difficulty which presents itself in the employment of such a contrivance is that of keeping the wicks equally well-trimmed. To obviate this, the flat wick was invented; and thus a thin sheet of flame was produced, which allowed of much more perfect combustion. Nevertheless, with all these improvements, the light of the lamp could not be increased beyond a certain point without its becoming dull and the wick sooty; and consequently for many years the lamp was rarely used in the apartments of the rich, for fear of its doing harm to the walls and furniture by its great tendency to smoke.

In 1780, however, as we have already said, a great change was effected in the art of illumination by the discovery of M. Argand of Geneva, who found that whenever a due supply of atmospheric air was furnished to the inside as well as the outside of a flame, the combustion of the oil might be kept up to any amount without danger from smoke or bad smell. The plan which he adopted for accomplishing this was very simple. He made the wick hollow, and placed a glass around it so as to secure a strong current of atmospheric air to both sides of the flame. We shall have occasion to describe the details of his contrivance when we come to the subject of the various Argand lamps at present in use. All subsequent improvements on this invention of M. Argand have been with the view of adjusting the wick, of regulating the supply of oil, of doing away with the shadow cast by the reservoir, and of directing the current of atmospheric air into the body of the flame. The first object was accomplished by means of a rack and pinion, or by a point working in the thread of a screw; the second by various forms of fountains, syphons, and, in the Carcel lamp, by means of a piston which is worked by machinery. The wick has also been modified in its construction so as to suit the condition of the oil; it is made of fine web when the oil is very fluid, and of coarse web when it is

thick. The third object has been accomplished by giving the reservoir an annular form—this was Count Rumford's invention—or by placing it above the level of the flame, as in Parker's lamps; and the fourth, by contracting the glass immediately around the wick, or by putting a metallic disc into the centre of the flame, as in the Vesta lamp; or by dropping a brass nipple over it, as is the case with the solar lamp. All these contrivances increase the supply of air; and, by breaking its course, they cause it to impinge upon the body of the flame.

For the combustion of volatile oils and naphtha, lamps of very different construction are required; especially in those cases where the oil or spirit is to be consumed in a gaseous form without the aid of a wick. We shall describe these lamps, which are of comparatively modern invention, when we speak of Beale's, Holladay's and Ludërsdorf's lamps.

With all lamps, however, the great principle that is to be kept in view is, so to adjust the supply of atmospheric air to the combustible, that on the one hand the flame shall not evolve smoke, and on the other it shall not be cooled or over-burnt; for, in the one case there is too little atmospheric air, and in the other there is too much.

Management of Lamps.—Lamps will not burn in a satisfactory manner if they are not kept clean and well trimmed; for, in the first place, nearly all the oils which are made use of at the present time are, more or less, drying in their nature, and consequently they are apt to become thick in the lamp, and to clog its several apertures. Whenever this occurs, the lamp ceases to burn; and there is no help for it but a good cleaning. This is accomplished by draining out all the oil as completely as possible, then charging it with a strong solution of soda or pearlash, which combines with the oil and forms soap. The solution ought to remain in the lamp for twenty-four hours, and it should be frequently agitated; but care should be taken not to spill any of the liquor over the paint or lacquering of the lamp, for fear of dissolving it off. After it has stood in this way for the necessary time, the soapy liquid may be run out, then washed clean away with warm water; and, finally, the lamp is to be well dried. Some of the very common oils are so liable to resinify, that it is necessary to change the wick every day: this is the case with the oils that are used in Parker's hot-oil lamp, and consequently it is trimmed with a very short wick. In the second place, the wick should be properly attended to: if a solid wick is used it should not be twisted too tight, for fear of stopping the capillarity for the oil; nor should it be too loose, for then it is apt to accumulate soot. If the Argand, or hollow wick, is employed, it should be selected with due regard to the quality of the oil; for a thick or fatty oil requires a coarse texture, and a very fluid oil a fine one. The top, or carbonized portion of the wick, should always be removed immediately before the lamp is lighted; for this is so changed by the action of heat, that the oil will not rise in it; indeed, the common oils are so disposed to char and clog this portion of the wick, that it sometimes requires removal several times in the course of an evening. The wick should be cut perfectly level, or the flame will be irregular, and will smoke. Lastly, in cold weather it is advisable to warm the oil before the lamp is lighted.

The relative Illuminating Power and Economy of different Lamps.—This is a subject which has not been well investigated; for the difficulties connected with it are extremely great. At the Exhibition of 1851, there were forty-nine lamps sent for examination; but the jurors declared that it was a matter of impossibility to test their value. M. Peclet is nearly the only person who has devoted attention to this subject; and the following table is constructed in great part from his investigations:—

Lamps.	Consumption per hour.	Luminosity in sperm candles of 120 grains.	Relative power for equal weight.
1. Vesta lamp without button (camphine)	140 grains	2·6	185
2. Ditto ditto ditto (with coal-naphtha)	136 „	2·0	147
3. Common Argand	350 „	4·0	114
4. Carcel lamp	630 „	7·0	111
5. Sinumbra, with lateral fountain	270 „	2·9	109
6. Thilorier's or Parker's lamp	767 „	7·6	99
7. Sinumbra, with fountain above	645 „	6·3	98
8. Common sinumbra	645 „	6·0	91
9. Gerard's hydrostatic	521 „	4·5	86
10. Common open lamp	103 „	0·8	77
11. Eclairage au gaz	343 „	2·1	61
12. Fountain lamp, with flat wick	165 „	0·9	54
13. Dome Argand	400 „	2·1	52

Varieties of Lamps.—These are so exceedingly numerous that it is not possible, in a work like the present, to give anything more than a very general account of the most important. Indeed, there are but few really distinct principles involved in the construction of lamps, notwithstanding that there are so many modifications in their form and arrangement; we shall have no difficulty, therefore, in understanding the construction of any lamp, after we have become acquainted with the following varieties. It is proper to add, that we are indebted to the "Encyclopædia of Domestic Economy" for many of the illustrations which we are about to offer, and that the reader will therein find a very good description of the lamps now in use.

1. **Common Oil Lamp, without any Glass.**—Of these there are several:—

(*a.*) *The Common Lamp of the Shetland and Orkney Islands* (Fig. 10).—This is contrived for the combustion of common fish-oil, and the wick that is used is nothing more than a bundle of dried rushes. A lamp of similar construction is used by the Esquimaux, who employ a wick of dry moss.

(*b.*) *The Common Street Lamp* (Fig. 11) was once to be seen at the stalls of poor tradesmen; though it is now almost entirely displaced by the common naphtha lamp.

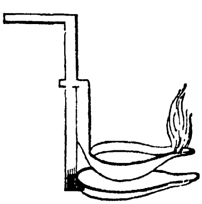

Fig. 10.

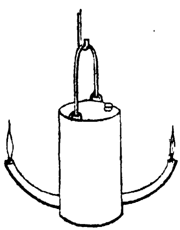

Fig. 11.

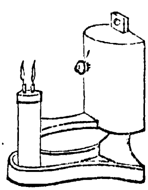

Fig. 12.

It is a tin vessel, with one or two spouts emerging from the sides close to the bottom. These are packed pretty tightly with cotton wick; and being constructed on the principle of the bird-fountain, the oil flows very freely to the top of the wick, but does not run over.

(*c.*) *The Fountain Lamp* (Fig. 12) **is constructed on nearly the same plan as the last; and as the reservoir for the oil is above the level of the wicks, the flame burns with the same** brilliancy **as long as** any oil remains.

(*d.*) *The Common Domestic Lamp* (Figs. 13 and 14) is made to fit a candlestick. It is a very economical lamp; though from the circumstance that the flame is situated at a considerable distance above the level of the oil, there is some difficulty in getting the lamp to burn when the oil is at all thick, or when the wick is clogged by age.

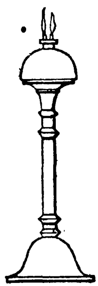

Fig. 13.

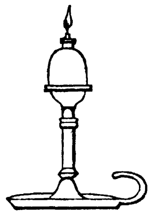

Fig. 14.

2. **Common Lamp with a glass or shade.**—Most of the preceding may be improved by surrounding the flame with a glass, to keep off the currents of atmospheric air, which cause the light to flicker. The principal of these are represented in Figs. 15, 16, and 17; and to the same category belong the floating night-lights (Figs. 18 and 19), which are either pieces of waxed wick supported on strips of tin, and kept floating by means of cork, or else little caps of thin brass pierced with a hollow glass tube, in which the oil rises and burns. The safety-lamp of the miner (Fig. 4) is nothing more than a common lamp, the flame of which is surrounded by a shield of wire-gauze; and in the lamp of Upton and Roberts there is an additional shield of glass.

3. **Common Lamp with Oxydator.**—It is found that when a current of atmospheric air is made to inpinge on the flame of a common lamp, the light is much more steady and brilliant. Various contrivances have, therefore, been adopted for the purpose of effecting this; as, for example, the bending in or contracting of the glass immediately around the flame (Fig. 20); or the fixing of a metal or mica disc around it (Fig. 21); or, better still, the dropping of a perforated nipple over the flame, as is seen in Fig. 22. The last constitutes the principle of the solar lamp, to which we shall have occasion to refer by and by. It was, we believe, first contrived by Mr. Roberts, the miner, and was applied to his form of the improved Davy.

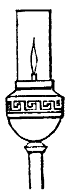

Fig. 15.

Fig. 16.

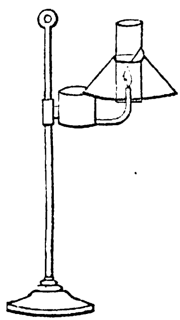

Fig. 17.

4. **The Argand Lamp.**—This differs from all others, in the circumstance that the wick as well as the flame is hollow; and it is so contrived that a current of atmospheric air plays on both sides of the flame, and so increases its brilliancy. There are several modifications of this lamp, of which the following are the most important:—

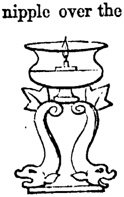

Fig. 18.

Fig. 19.

(*a.*) *Common Argand Lamp* (Fig. 23), which consists of a vase *a* to hold the oil; a cistern *b* to supply the burner; and an arrangement *c* for adjusting the hollow wick, and

allowing a supply of atmospheric air on both sides of the flame. The oil is put into the vase *a* by unscrewing it from *b*, and then running in the oil through the hole *d*, or else through the aperture in the bottom, which is usually closed by the plug *f*. The hole *d* is then closed by drawing up the handle *g*, which communicates with a sliding tube *h*, and the vase is returned to its place on *b*. When the lamp is lighted, the handle *g* is to be depressed: this causes the oil to escape through the hole *d* into the cistern *b*; and from this it runs by the side tube *i i* into the conical chamber *o*, which contains the wick *n*. This chamber consists of two tubes, *k k*, *l l*, one within the other, and joined at *m m*, so as to make a closed receptacle for the oil. In this receptacle the wick *n* plays freely up and down; and it is kept constantly immersed in oil, as high as the aperture *d*, in the cistern *b*. *p* is a cup placed at the bottom of the chamber to receive any oil that may run over from the wick. Atmospheric air rises freely through *c* into the centre of the flame, and it also blows upon the exterior of it: the cause of the current of air is the glass chimney which rests on the top of the burner.

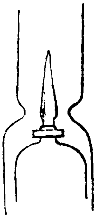

Fig. 20.

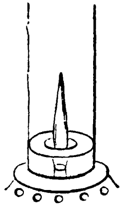

Fig. 21.

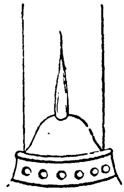

Fig. 22.

Many forms have been given to this lamp of M. Argand, according to the purpose which it is intended to serve: thus, there is the reading or Cambridge lamp (Fig. 24), the well-known table lamp (Fig. 25), and the suspended lamp.

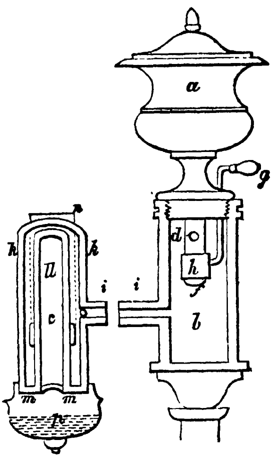

Fig. 23.

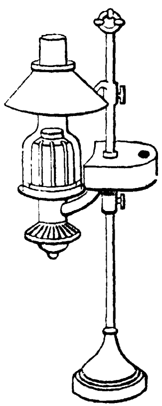

Fig. 24.

(*b*.) *The Rumford or Annular Table Lamp* is an improvement on the last. It was contrived by Count Rumford, for the purpose of avoiding the deep shadows which are produced by the reservoirs of the preceding; and it became so great a favourite that even to this day it is very generally used. The oil is contained in a hollow ring which is placed a little below the level of the flame; and the cistern is fed by means of two tubes, which also serve as supports. In order to diffuse the light still more, the burner is surrounded by a ground-glass shade, which almost entirely conceals the ring (Fig. 26).

(*c.*) *Parker's Sinumbra Lamp* was patented in 1820. It was called the shadowless lamp, because it did away with the slight shadow which is always perceptible in the

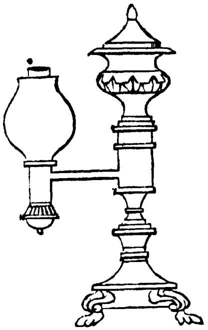

Fig. 25.

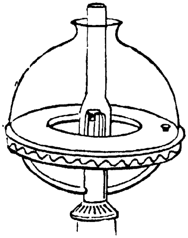

Fig. 26.

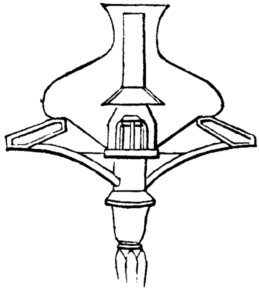

Fig. 27.

last. The improvement is threefold:—first, the annular reservoir is bevelled off from above, so as to present a very thin edge on the outside; secondly, the glass is shaped in such a manner as to diffuse the light over the edge of the ring, and under it; and, thirdly, a conical reflector is placed around the inner glass a little above the flame. All these arrangements are represented in Fig. 27, which shows the lamp in section.

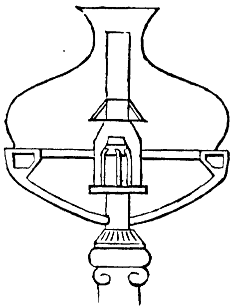

Fig. 28.

(*d.*) *Quarrel's Sinumbra Lamp* (Fig 28) is another contrivance for effecting the same object as Parker's; but the bevelling of the reservoir is on the under surface of the ring, instead of the upper; and the ground-glass shade is made sufficiently large to reach to the very outer edge of the ring.

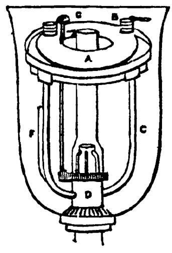

Fig. 29.

(*e.*) *The Iris Lamp* is one of the most recent improvements of the Rumford and Argand: it differs very little from the preceding, except that the outer edge of the annular chamber is reduced to a mere bead; and the ground-glass shade is not only brought to the very front of the ring, but its body is formed in such a way as to bulge over it. By these contrivances the shadow of the reservoir is reduced to a minimum.

(*f.*) *Quarrel's Albion Lamp.*—This marks the next attempt to improve the Argand, by carrying the reservoir for the oil over the flame, and, therefore, out of the way of the shadow, instead of having it, as in Rumford's contrivance, around it and a little below it. The construction of this lamp is represented in Fig. 29: A is the reservoir for holding the oil, which is introduced through the two valve-cocks B; C is the tube that

conducts it to the cistern D; and F is a syphon-valve for admitting atmospheric air to the reservoir, so as to supply the place of the consumed oil. G is a pinion for regulating the height of the wick. The whole is enclosed in a tulip-shaped glass; and, with the exception of the side-tubes, there is nothing to produce a shadow.

(*g*.) *Parker's Hot-oil Lamp* is constructed somewhat like the preceding, though a contrivance is adopted for making the oil hot before it reaches the wick; by which means it becomes more fluid, and burns with greater facility. Fig. 30 shows the plan of this lamp. The reservoir is above the flame, and the top of the glass is fitted into an iron chimney, which radiates heat very freely to the reservoir. The oil passes down through a lateral tube to the cistern, and there is a stop in the tube to cut off the supply of oil when necessary. The wicks are very short; and instead of their being adjusted by the rack and pinion, a movement is given to the glass, which, by its position, regulates the intensity of the flame. A painted shade is put over the whole, in order that the reservoir may be hidden. The advantage of this lamp is, that it will consume the very commonest oil without producing an unpleasant smell. One caution, however, is necessary in the management of it—namely, that the reservoir be filled quite up with oil before the lamp is lighted. If this be not attended to, the air contained in the chamber will expand by the action of the heat, and the oil will be forced out over the wick and will run about.

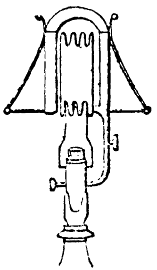

Fig. 30.

(*h*.) *Keir's Fountain Lamp.*—In all the preceding contrivances, the supply of oil to the flame is chiefly effected by the capillarity of the wick. In some cases it is assisted by the gravitation of the oil from a reservoir situated above the level of the burner. But it has always been thought desirable to have the reservoir in the stem or body of the lamp, so that the unsightly appearance of the chamber might be avoided, and the shadow which it invariably casts to a greater or less extent upon surrounding objects, entirely prevented. This, however, can only be accomplished by means of some power whereby the oil shall be pressed up from the well in which it is contained, to the level of the flame. "To effect this, two methods have been resorted to: one is on a hydrostatic principle, in the manner of Hiero's fountain, where the oil is placed in the body of the stem, and is raised to the wick as it is wanted by the pressure of a column of some fluid: in the other method, the oil is forced by clock-work mechanism, as in the lamp of Carcel of Paris. The first successful attempt of this kind in England, was in the lamp invented by Mr. Keir, about forty years ago, upon a hydrostatical principle; and although it is not used at present, being superseded by contrivances of a similar kind by other manufacturers, yet it will serve to illustrate the general nature of these lamps, of which several varieties have been brought partially into use."—(Webster and Parker, p. 159). Fig. 31 represents Keir's lamp, the vase and pedestal of which are hollow. *a* is a tube into which a certain quantity of salt-and-water, having three times the specific gravity of oil, is put. Upon this is poured the oil until the tube is full. The brine, or solution of salt-and-water, runs down into the pedestal of the lamp; and when the oil is poured upon it, the latter by its weight forces up the former through a second tube *b*, into a chamber *c*, in the upper part of the body of the lamp, and the oil

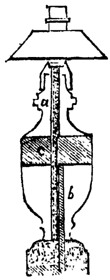

Fig. 31.

takes the place of the brine in the pedestal. It will be noticed that the tube *a* reaches only to the top of the chamber in the pedestal, while the tube *b* passes down to the bottom of it. The brine is represented by diagonal lines, and the oil by dots. Now, in consequence of the great weight of the brine, as compared with that of the oil, the latter is forced up to the burner as fast as it is consumed; and thus, by a sort of natural spring, the flow of oil to the wick is constantly maintained. After a supply of salt-and-water has once been introduced into the lamp, there is no necessity for a further addition of it.

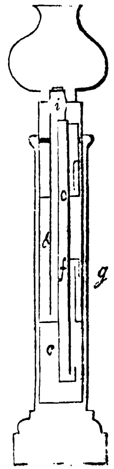

Fig. 32.

Similar lamps have been constructed on the same principle by King, Barber, and others; but they are all difficult to manage, and hence they are not much in vogue, although they generally have a very light and elegant appearance.

(*i.*) *Parker's Fountain Lamp* (Fig. 32) is a very complicated apparatus, which, like the fountain of Hiero, owes its action to compressed air. Externally it presents the appearance of a column surmounted by the lamp; but within this column there is another cylinder which contains the oil. This cylinder must be removed before the lamp can be charged. It is divided crosswise into three compartments, *a*, *b*, *c*, which have no direct communication with each other. Through the centre of the whole there passes a tube *f*, which is open at top, and at bottom it communicates by a sort of valve with the compartment *c*; it also communicates with the compartment *a*, by means of a hole which is seen near the top of the tube. The three compartments or chambers are therefore in indirect communication with each other; thus *a* communicates through the hole just mentioned with the tube *f*, this communicates by its bottom valve with compartment *c*, and this, by means of a tube and valve *g*, with the middle compartment *b*; and *b* communicates by means of an ascending tube with the burner *i*, in which the wick is placed: so that if oil be poured into the upper opening of the tube *f*, it will fill the compartment *c*; and then on turning the apparatus upside-down, the oil will flow through *g* into the middle compartment *b*. On restoring the cylinder to its proper position, the oil cannot return to *c*, because of the peculiar form of the contrivance *g*—consequently it remains in the middle chamber; and now, on refilling *c* through the tube *f*, the air in the lowest chamber is compressed, and it forces the oil in *b* up through the lateral tube to the burner *i*. The chamber *a* is filled at the same time as *f*, and its contents flow as fast as they are wanted through the hole in the tube *f*, and thus keep up a supply to the pressure-column. Every time the lamp is charged it is inverted, in order that the oil in *c* may flow into *b*; and then it is returned to its original position, and recharged with oil. This lamp was reported on by the French Academy of Science, and it was formerly much used in India; though now it is superseded by the Iris lamp.

(*k.*) *The Carcel Lamp* is very generally used at the present time. It presents much of the appearance of the last described; but instead of the flow of oil being effected by means of atmospheric elasticity, it is accomplished by the aid of machinery moved by clock-work. In this way the oil is raised, or rather pumped up, to the wick, so as to keep up a constant supply by continually overflowing it. The oil drips back into the cistern below; whence it is drawn up again and again, until it is all consumed.

(*l.*) *The Solar Lamp.*—This is Roberts's great improvement on the Argand, although

it was patented by Mr. Bynner. It is a contrivance for increasing the supply of atmospheric air to the flame, and so enabling it to consume a larger proportion of oil, and thus to give out a greater body of light; besides which, it effects a more complete combustion of the oil, and, therefore, produces a more intense light. In all the common forms of Argand, the air passes straight up through the burner, and only slightly impinges on the two sides of the flame; but in this contrivance the current of air is broken, and made to blow in upon the flame. The apparatus which effects this is a small cone or nipple, that is dropped down over the flame (Fig. 33).

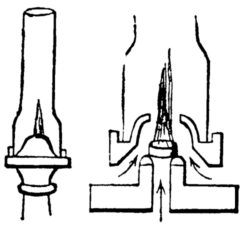

Fig. 33.

A still greater improvement on this principle is that of Quarrel, in which he causes a second current of air to enter under the glass, and thus to assist the other in blowing on the flame (Fig. 34); and by introducing a button into the centre of the flame (as was also originally proposed by Mr. Roberts), this inner current of atmospheric air is likewise deflected, and thus we get the greatest possible amount of oxydation (Fig. 35). By the adoption of such contrivances as these, almost any kind of oil, even the commonest fish-oil, may be burnt without smell.

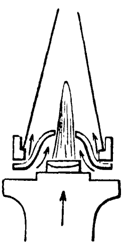

Fig. 34.

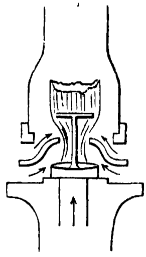

Fig. 35.

(*m.*) *The Bude Light* of Mr. Goldsworthy Gurney is only an extension of the preceding principle. Roberts increased the supply of atmospheric oxygen, by means of the nipple, which others patented and applied to the solar lamp. Mr. Gurney, however, uses a jet of pure oxygen, or of an atmosphere rich in oxygen, which he throws into the centre of the flame by mechanical power; and by this means he increases combustion and light to an enormous extent. This light requires complicated apparatus for its production, and hence it has never come into general use.

(*n.*) *The Argand with Concentric Wicks.*—Many years since Mr. Webster suggested that Argands might be made with two circular wicks, one within the other; and Sir Humphry Davy referred to the invention as one well adapted for obtaining heat for chemical purposes. A lamp on the same principle, with four concentric wicks, has since been constructed, by M. Fresnel, for light-houses; and, according to Dr. Brewster, it gives a light equal to forty common Argands; but the heat produced by the lamp is very intense.

5. **Lamps for Burning Solid Fats.**—The commonest form of these is the saucer and central-wick lamp, which may be seen so frequently in France during the nights of illumination; but a more agreeable form has been given to this kind of lamp by the Hon. G. Cochrane, who took out a patent for it a few years ago. His lamp is very much like an ordinary Argand, but it has a piece of metal over the flame which communicates with the chamber containing the fat, and thus keeps it warm and liquid (Fig. 36). The fats which are best suited for this lamp are cocoa-nut and palm; but tallow and kitchen-stuff may also be used.

6. **Camphine or Vesta Spirit Lamps.**—These are the names given to the lamps which are constructed to burn the highly rectified oil of turpentine—a liquid which Mr. English originally prepared and patented under the name of camphine. Mr. Young, of Queen Street, Cheapside, has devoted great attention to the manufacture of these lamps, which he calls *Vesta spirit lamps.* The reservoir for holding the camphine is made of glass, in order that the heat from the burner may not be communicated to it: in fact, every precaution is taken to guard against such a result; for the wick, instead of being supported on a long metal tube, which passes down into the body of the oil, as is the case with the common Argand lamps, is merely held at the top by a narrow ring, while the remainder of the wick floats freely in the spirit; besides which, the burner is insulated from the lamp by a collar of wood. The next point of importance in their construction is that which ensures an abundant supply of atmospheric air; for if this is not provided for, the turpentine burns with a remarkably sooty flame, and evolves a large quantity of blacks. This is effected by having a slit in the side of the wick so as to allow the atmosphere to pass freely into its interior; and the nipple, or cap, of the solar lamp is used to break the outer current of air and blow it into the flame; besides which, the chimney is very tall, and it is bulged in, or contracted, at the point where it reaches the flame. In the larger kinds of camphine lamps, the button of Mr. Roberts is also introduced into the interior of the flame, so as to break the inner current of atmospheric air (Fig. 37). And then, in addition to all this, a cylinder of perforated brass is put around the vent-holes of the burner, so as to prevent the ill effects of extreme draughts. The principles, therefore, which are kept in view in the construction of these are —1st, to prevent the heating of the liquid; 2nd, to ensure a large supply of atmospheric air; and 3rd, to guard against the influence of external draughts. One of the great advantages of the Vesta lamp, is the intensity and purity of the flame. Dr. Ure says that a lamp which consumes two ounces of camphine in an hour, gives the light of nearly twelve sperm or wax candles of three or four to the pound. Our own experiments show that the smaller lamp which has no button, consumes about 140 grains per hour, and gives the light of two and a half sperm candles, each burning at the rate of 120 grains per hour; while the larger lamp, which has the button, consumes about 540 grains of camphine per hour, and gives the light of seven sperm candles.

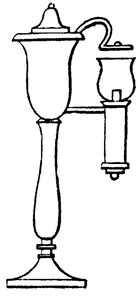
Fig. 36.

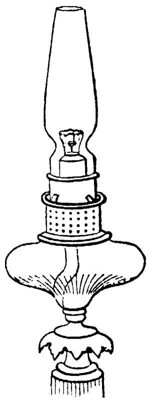
Fig. 37.

Among the disadvantages of the Vesta lamp are its liability to smoke, and its disagreeable smell. The former may arise from bad management, or from a resinification of the camphine—a circumstance that is sure to occur if the tin-can containing the liquid is not kept well corked, or if too much liquid is put into the lamp for an evening's consumption.

7. **Naphtha Lamps.**—Of these there are two kinds—viz., the Argand naphthas, which are constructed exactly like the preceding; and the flat-wicked lamp, which is represented in Fig. 38. In the latter, the air is directed upon the exterior of the flame

by means of two lateral pieces of tin, which incline inwards as they ascend to the wick; and the supply of air is regulated by an external opening or valve, which may be shut up to any extent. When naphtha is burnt in a small Vesta lamp, it is consumed at the rate of about 136 grains per hour, and it gives the light of two standard sperm candles; when burnt in the large one, its consumption is 486 grains per hour, and its light is equal to nine sperm candles. The disadvantages of these lamps are, the unpleasant smell of the naphtha, the liability to smoke, and the danger of explosion; for naphtha, being much more volatile than camphine, is likely to give off vapour, which with the air forms an explosive mixture. Great caution is therefore necessary in managing these lamps.

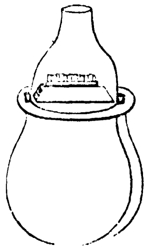

Fig. 38.

8. **Gas or Vapour Lamps.**—Several attempts have been made at various times to burn inflammable liquids without a wick. The earliest and simplest of these is

(*a*.) *The Common Floating Night-lamp*, which is nothing more than a small cup of metal pierced in the middle with a small glass tube. The oil rises by capillary attraction in the tube, and may be ignited.

(*b*.) Another form of *self-generating lamp* is represented in Fig. 39, where two tubes, *a a*, bring the oil down from the annular reservoir, and convey it into a cistern, whence it rises by the tube *b* into a cup which has a cylinder filled with it, pierced with a number of small holes that serve for jets. When the lamp is trimmed, alcohol is poured into the cup, and set fire to. This in the act of burning makes the cylinder so hot that the oil within it is converted into gas; and this escaping through the hole or jets, is fired and burns with a brilliant light. The heat produced by the combustion of the gas, keeps up the supply. A glass is placed around the burner to protect it from external currents, and to prevent the flame from smoking.

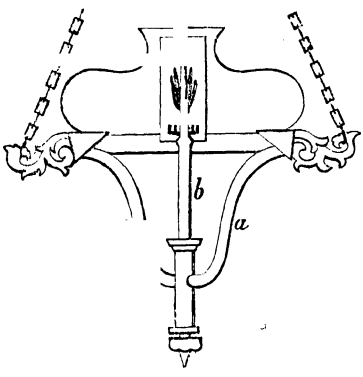

Fig. 39.

(*c*.) A mixture of camphine or highly rectified spirits of turpentine with alcohol, is burnt on the Continent in a lamp that was originally designed by Ludërsdorf, but which has been patented in France by Ribot under the name of "*Eclairage au Gaz liquide.*" The French lamp is represented in Fig. 40. It is an elegant-looking lamp, the body and stem of which are composed of cut glass. Fig. 41 exhibits the mechanism by which the spirit and turpentine are converted into vapour. *a* is the wick which floats in the liquid and conveys it up through the tube *b* into *c*, which is the vapour chamber; *d* is a cap of brass, which when heated effects the vaporization of the liquid, and causes the gas to escape through three little holes at its base; *f* is the collar for holding the glass; and *g* is a handle for turning the liquid off or on. When the lamp is to be lighted, it is filled up with mixed spirit; and the glass being removed, the handle *g* is to be turned from

the left to the right. A ring of wire-gauze, saturated with the spirit, is then lighted and brought down over the cap d as low as e. This is to be kept burning until the metal cap and chamber are sufficiently heated to generate gas, which will escape through the holes and take fire. When this has occurred, the glass is to be replaced; and the burning jets will keep up the desired temperature. Instead of turpentine and alcohol, a mixture of equal parts of spirits of wine and coal-naphtha, or even coal-naphtha itself, may be used. The disadvantages of the lamp are its liability to go out with the least draught of air, and its danger of exploding.

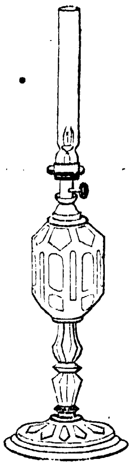

Fig. 40.

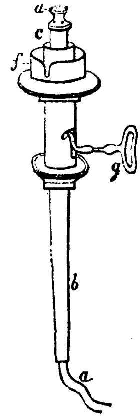

Fig. 41.

(*d.*) *The Common Naphtha Lamp* is now extensively employed by poor trades-people who have their stalls out of doors. The construction of this lamp will be understood from Fig. 42: a is the reservoir for the naphtha, from the bottom of which there passes a tube b, which supplies the fluid to the burner c. A stop-cock is inserted into the middle of the tube, in order that the supply of naphtha may be regulated, or even cut off altogether, when it is not wanted at the burner. Fig. 43 exhibits the construction of the latter: the naphtha enters by the tube a, and it flows out of a small hole which is in the lower arch of the burner, and trickles down into a small cup b; here it is lighted, and soon the combustion of the naphtha produces so much heat that it makes the whole body of the burner very hot. This causes the naphtha to assume the form of vapour or gas; and as it issues out of the small hole, it is forced up against the bottom of the disc c; and thence it comes spreading out in a star-like form all round the burner. This form is given to it by the little breaks of perpendicular wires which descend from the bottom of c; another small disc is placed below this to prevent the flame from bounding back upon the jet whence it issues from the tube; d is a small wire which is withdrawn when the interior of the burner wants cleaning.

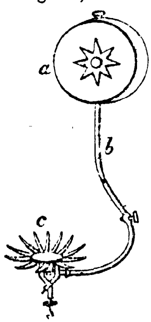

Fig. 42.

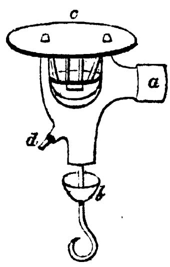

Fig. 43.

(*e.*) *Beale's Naphtha Lamp.*—This form of lamp was invented some years ago by Mr. Beale of London: it consists of a vessel a (Fig. 44) in which the naphtha is placed; thence it flows by a lateral tube into the cup-shaped cistern b, and it is prevented from overflowing by reason of its being constructed in the same way as a bird-fountain. A tube passes up through the bottom of the cistern, and reaches a little above the level of the liquid: this tube is placed in communication with a reservoir

or gasometer containing air. Lastly, a brass cap *d*, having a hole in the top, is placed upon the cistern; the lamp is put into action by removing the cap and setting fire to the naphtha; air is then blown through the tube *c*, and the cap is gradually brought down into its place in the cistern, care being taken that it is sufficiently heated during its descent to keep up the volatilization of the naphtha. When this is properly managed, the air which passes through the tube *c* carries with it so much naphtha vapour as to become inflammable; and as it issues from the hole in the top of the cap, it burns with a brilliant jet of flame.

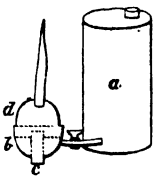

Fig. 44.

We have not thought it necessary to give a description of the different ornamental contrivances for setting up and supporting lamps, &c.—as, for example, candlesticks, candelabra, chandeliers, &c.; for this would entail a very elaborate account of the principles of ornamentation, which is not suited to the object of this work.

ON GAS.

General Remarks.—Long and long enough before gas was manufactured artificially, it was generated in the great laboratory of nature by the action of terrestrial heat on large accumulations of vegetable matter, as beds of coal. The products of this action made their way to the surface of the earth, and escaped in the form of gas and petroleum; both of which are highly inflammable. The fires thus generated commanded attention at a very early period, and altars dedicated to the gods were erected over them. At the time that the Persians, under the command of Mardonius, overran Greece, there were innumerable altars lighted up in this manner; and so much were they reverenced by the Greeks, that when the Persians were defeated at the battle of Platæa and driven from the country, the two victorious generals, Pausanias and Aristides, were directed by the Oracle of Delphi to build an altar to Jupiter, their deliverer, and not to offer any sacrifice upon it until they had extinguished all the fires throughout the country which had been polluted by the Persians, and had relighted them with the sacred fire from Delphi. In Plutarch's life of Alexander, we are told that when that monarch arrived at Ecbatana, "he was particularly struck with a gulf of fire, which streamed continually, as from an inexhaustible source. He admired also a stream of naphtha not far from the gulf, which flowed in such abundance that it formed a lake. The naphtha in many respects resembles bitumen, but it is much more inflammable; before any fire touches it, it catches light from a flame at some distance, and often kindles all the intermediate air. The barbarians, to show the king its force and the subtlety of its nature, scattered some drops of it in the street which led to his lodgings; and standing at one end, they applied their torches to some of the first drops, for it was night. The flame communicated itself swifter than thought, and the street was instantaneously all on fire."

For several thousand years the Chinese province of Se-tschuan has been celebrated for the quantity of inflammable gas that issues from the earth; and to this day it is said, that the gas which escapes from the ground in the neighbourhood of Pekin is collected by the inhabitants and used for lighting the streets and houses. The holy fires of Baku, near the Caspian Sea, have a similar origin; and jets of inflammable air

are evolved at Pietra Mala, not far from the road between Florence and Bologna; at Maina, which is a few miles from Modena; at Lycia in Asia Minor; and at the Artesian wells of Lichweg in Schauenburg. In this country the gas is abundantly evolved from the fissures of coal mines, where it is known by the name of *fire-damp;* and it is also evolved from stagnant pools, when it is termed *marsh-gas.* At the village of Wigmore in Herefordshire, inflammable gas has on several occasions escaped from the earth in such large quantity, that it has been made the means of lighting the neighbourhood. The same has been the case at Charlemont in Staffordshire, and at Bedley near Glasgow. Not long since a considerable jet of gas was discharged from the Chat Moss, near to the Manchester and Liverpool Railway, and it was used by a neighbouring farmer for the purpose of working a small steam-engine. In the village of Fredonia, in the State of New York, the gas issues from the earth in such abundance, that the inhabitants collect it, and employ it for lighting the streets.

History of Gas Lighting.—It would naturally be supposed that facts like the preceding would, at a very early period, have commanded the attention of practical men of science, and that some effort would have been made to imitate the process which they saw going on in nature. Some, indeed, have thought that the ancient Greeks were really acquainted with a mode of generating gas, and that the chief priests took advantage of such knowledge in exciting the veneration of the people. The altar in the Temple of Ægina is described by Dr. Dodwell as having a round hole, thirteen inches in diameter, cut out of the top of it. This hole communicates with another which passes down through the solid stone to the depth of several feet, and there it opens into a cavity which is supposed to have contained fire that was always burning. He says that nothing more was necessary than to pour oil into the upper opening; and as it trickled down, it would be converted into gas, which would burst forth as flame, and appear to have a miraculous origin. But however possible, or even probable, the truth of this supposition may appear to be, it is certain that nothing of the kind was practised in Europe until the beginning of the seventeenth century, when Van Helmont, the physician and alchymist of Vilvorden, was led, in the course of his investigations, to expose a quantity of animal and vegetable matter to the action of heat in a closed vessel. By this means he obtained a vapour or spirit that burnt with a bright flame; but he little imagined that this *gaz fuliginosum*, as he termed the vapour, would one day become an agent of general illumination. Nor even at a much later period—namely, in the year 1726—when Dr. Hales informed the chemists of his time that by distilling a few grains of Newcastle coal he had obtained an equal number of cubic inches of inflammable air, could it be supposed that a similar experiment on a very gigantic scale would be daily performed in every city in Europe, and that millions upon millions of cubic feet of that subtle, inflammable material would be made to traverse, unseen, along the highways of the land, and be the means of lighting them up into perpetual day.

Again, we may take up the history of our subject from another important discovery. Some time before the death of the Honourable Robert Boyle (1691), a letter was written to him by the Rev. Dr. Clayton on the subject of distilling pit-coal. That letter was published many years afterwards—namely, in the year 1739—in the Transactions of the Royal Society; and the author states that from an examination of some inflammable vapours which were given off from a ditch near Wigan in Lancashire, vapours which had been collected and examined by Thomas Shirley in 1659, he was led to conclude that they came from the coal of the neighbourhood, which was acted on by terrestrial heat. Accordingly, he obtained a portion of the coal, and distilled it in a

retort over an open fire. By this means he obtained a phlegm, which first passed over; then a black ore; and lastly a spirit, which he could nowise condense, for it forced the luting of his apparatus and broke his glasses. This spirit was coal-gas; and on discovering its inflammable nature, he was in the habit of collecting it in bladders and oiled silk-bags, and thus preserving it for the amusement of his friends.

As yet, however, he had not leart to burn it from a metallic jet, for he was accustomed to prick a hole in the bag, and then to set fire to the gas as it issued forth. For a period of more than fifty years these interesting facts were allowed to slumber, and no one entertained the idea of applying them to any useful purpose. At length, in the year 1792, just one hundred years after Boyle's death, an ingenious engineer and miner of Cornwall, whose name was Murdoch, conceived the notion that gas might be conveyed through pipes to a distance, and be thus employed as an illuminating agent. Acting upon this idea, it was not long before he had the satisfaction of seeing his house and offices at Redruth lighted up with Dr. Clayton's subtle spirit. He also collected the gas in bladders, and used it as a means of lighting himself along the road between the mines and his own house; for which piece of ingenuity he acquired the reputation of a wizard. Soon after this Mr. Murdoch was employed in the establishment of the celebrated engineers, Messrs. Bolton and Watt. There he erected apparatus for the manufacture of gas; and at the Peace of Amiens in 1802 he lighted up their factory for the first time with this agent. About a year afterwards gas was generally employed in all the workshops of the factory; and in 1804 he set up a similar apparatus in several of the large cotton-mills of Lancashire—one of the earliest of which was at the establishment of Messrs. Phillips and Lee at Manchester.

Ten years after this—namely, in 1813—the manufacture of gas had extended to London, and in that year Westminster Bridge was lighted with it. Mr. Clegg gives an account of the horrors of the lamp-lighters when they first beheld the burning gas, and how he was obliged to light the lamps himself for some time, on account of the fears of the people. Even such men as Sir Humphry Davy and Sir Joseph Banks were unable, for many years after this, to overcome the prejudices which existed in their minds concerning it; and they thought the scheme a wild and dangerous one. The public, however, soon became reconciled to it; and in 1814 the oil-lamps were removed from the streets of St. Margaret's, Westminster, and gas-lights were put into their places. This was the first parish that entered into a contract to have the streets lighted with gas.

In that same year the Allied Sovereigns came to this country; and as they were to be fêted and feasted in no ordinary manner, a great opportunity occurred for the use of gas, where no other means of illumination could be employed. On the ornamental water of St. James's Park a magnificent pagoda was erected; it was furnished with thousands of jets of gas, and in an instant, as if by magic, they all burst forth into flame, and gave the building the aspect of a brilliant fountain of fire. At one of the City feasts, the Guildhall was lighted up in a similar manner; and we are told by one of the journals of the time, that the light was "clear as summer's noon, but soft and undazzling as moonlight, forming a magnificent combination worthy the inuguration of the presiding citizen of the great city." Up to that time the gas was marvellously impure, and its fœtid odour proved an insurmountable barrier to the use of it in private houses. By and by, however, the attention of chemists began to be directed to this point; and as the processes of manufacture and purification were perfected, the use of gas became more and more general; so that in 1822 there were four great companies

established in London, having forty-seven gasometers, supplied by 1315 retorts, which generated upwards of 397,000,000 cubic feet of gas annually, supplying about 61,000 private lamps, and 7,268 public ones. In five years this quantity had nearly doubled itself; and in ten years more it was doubled again, so that in the year 1837 it had acquired so much importance as to become a subject for parliamentary investigation. In that year a paper was laid before a Committee of the House of Commons, by Mr. Hedley; from which we gather, that for lighting London and its suburbs, a capital of £2,800,000 was employed. This yielded a revenue of £450,000, and furnished an annual supply of 1,460,000,000 cubic feet of gas. Twelve years after this, we are told by Mr. Croll, in his evidence before the Committee of the House of Commons on the Great Central Bill, that the consumption of gas in the metropolis, during the year 1849, was more than double that of the preceding estimate; for it amounted to 3,200,000,000 cubic feet annually, of which the City alone consumed 500,000,000. This was distributed to 2,678 public lights, and to a multitude of private consumers. The area of the metropolis is about sixty-six square miles, and that of the City one. In the former space there are, according to Mr. Barlow, about 2,400 miles of main-pipes, which run along 1,500 miles of streets; and in the latter there are about 110 miles of main-pipes, which light up 75 miles of streets. The surveyor to the Corporation states, in one of his reports, that the length of public way in the City is only 51 miles, and that the lamps average 54 to each linear mile, or 1 in every 33 yards. But perhaps the best estimate of the enormous extent to which this branch of industry is carried on, may be formed from a statement made by Dr. Hoffman, on the authority of Mr. Lowe, who is one of the oldest gas engineers of the present time. He says, that about 6,000,000 tons of coal are annually consumed in England in the manufacture of gas; and as each ton of coal does, on the average, produce about 10,000 cubic feet of gas, we have the almost incredible quantity of 60,000,000,000 cubic feet of gas produced yearly. And to this it may be added, that almost every town of upwards of two thousand inhabitants has its machinery for the manufacture of gas.

Action of Heat on Organic Matter.—As a preliminary to the study of gas-making, it is necessary that something should be known of the changes which occur when animal or vegetable matter is subjected to the action of heat. Chemists have shown that the effects vary with the temperature. At first, when the heat is not considerable, the matters evolved consist of aqueous vapour, organic acids, ammonia, and various combustible fluids which are soluble in water. In the second period, when the heat is somewhat higher, the products are carbonic acid, carbonic oxide, water, and a number of oleaginous or empyreumatic compounds, which are not soluble in water; and lastly, when the temperature is still higher, the products of the decomposition are hydrogen, marsh-gas, and sundry carbo-hydrogens, which retain their gaseous condition. In the case of non-nitrogenous bodies, as wood, resin, fat, oil, &c., the chief products of distillation are water, acetic acid, naphtha or wood-spirit, volatile oil, tar, paraffine, creosote, carbonic acid, carbonic oxide, olefiant gas, super-olefiant gas, marsh-gas, hydrogen, &c.; and when the substance contains nitrogen and sulphur, as is the case with coal, there are evolved ammonia, aniline, leukol, picoline, lutidine, &c., together with cyanogen, sulpho-cyanogen, and all the compounds just named. In every case there remains in the retort a quantity of carbonaceous matter, which goes by the name of coke, or *caput mortuum*.

Of the gases which are thus evolved, the most important are hydrogen, carbonic oxide, marsh-gas, olefiant gas, and various hydrocarbons, which give to gas its high

illuminating power: all the others are positively injurious, and ought, therefore, to be got rid of before the gas is supplied to the public. An examination of the quality of these gases will readily convince us that they may be divided into three kinds—namely, the light-giving gases, the diluters, and the positive impurities. Of the *light-giving gases*, the following are the most important:—

(*a.*) *Olefiant gas* (C^4H^4): a compound that was discovered in the year 1795, by the associated Dutch chemists, and was so named from the property which it has of forming an oily-looking fluid when it combines with chlorine. It is an odorless gas, having a specific gravity of 0·97. It burns with a bright yellow flame, and consumes three times its bulk of oxygen, or nearly fifteen times its bulk of atmospheric air, producing twice its volume of carbonic acid. The gas is readily condensed by chlorine, bromine, or anhydrous sulphuric acid, and it is also absorbed to a slight extent by water.

(*b.*) *Other hydrocarbons*, as *Propylene* (C^6H^6), or the super-olefiant gas of Dalton and Henry, *Etherene* (C^8H^8), or the volatile gas of Faraday, and perhaps some others of a like atomic composition, are met with in most of the illuminating gases of commerce. These, like the last, consist of equal proportions of carbon and hydrogen. They are very condensable by chlorine, bromine, and fuming sulphuric acid, and they burn with a very bright sooty flame.

The *diluting gases* are marsh-gas, hydrogen, and carbonic oxide. These are important constituents of common gas, because they serve as the purveyors of the rich illuminating hydrocarbons, which could not be burnt alone.

(*a.*) *Marsh-gas*, or *light carburetted hydrogen*, is a compound of one atom of carbon and two of hydrogen (CH^2). It is about half as heavy as atmospheric air, and it burns with a bluish flame—that is, tipped with yellow. It consumes twice its bulk of oxygen, or nearly ten times its bulk of air; and it produces its own volume of carbonic acid.

(*b.*) *Hydrogen* is the lightest of all known substances. It is fifteen times lighter than atmospheric air. It burns with a pale blue flame, and consumes only half its bulk of oxygen, or two and a-half times its bulk of air; the sole product of its combustion being aqueous vapours.

(*c.*) *Carbonic oxide* (CO) is a little lighter than atmospheric air. It burns like the preceding, with a blue flame, and consumes only half its volume of oxygen. The product of its combustion is its own bulk of carbonic acid.

The *impurities of gas* are carbonic acid, ammonia, sulphuretted hydrogen, bisulphuret of carbon, tarry matter, and various compounds of cyanogen and sulphur.

(*a.*) *Carbonic acid* (CO^2) is a very heavy gas—its density being about 1·5. It is not only itself incombustable, but it has the power of checking the combustion of all inflammable gases. It is freely absorbed by lime and other alkalies. Water takes up about its own bulk of the gas.

(*b.*) *Ammoniacal gas* (NH^3) is about half as heavy as atmospheric air. It is not combustable, unless it is decomposed by the heat of some other burning body; and then the hydrogen of the gas burns in the usual manner. Ammonia is readily absorbed by water, and by solutions of acids and metallic salts. It is known by its communicating a red colour to turmeric paper, and by its fuming with muriatic acid.

(*c.*) *Sulphuretted hydrogen* (HS) is a most unpleasant-smelling compound; it is a little heavier than atmospheric air, and it burns with a pale-blue flame that evolves the odour of a burning match. When plenty of atmospheric air is present, the products of its combustion are water and sulphurous acid; but if the supply is limited, water alone

is formed, and the sulphur is precipitated. The sulphurous acid quickly absorbs more oxygen, and becomes sulphuric acid,—a compound that exerts a most destructive influence on every kind of textile fabric. When sulphuretted hydrogen escapes into the air without burning, it discolours lead paint and tarnishes silver. On these accounts, sulphuretted hydrogen is regarded as one of the most injurious compounds of ordinary gas. It is absorbed by lime, and by the salts of iron, zinc, copper, and lead; and the test for it is a piece of white paper dipped in a solution of sugar of lead. On exposing paper while damp to the action of the gas, the lead-salt is quickly discoloured; and thus the smallest trace of sulphuretted hydrogen may be easily recognized.

(*d.*) *Bisulphuret of carbon* (CS^2) is even a more serious impurity than the last, for it not only produces the same acid compound by its combustion, but it is also more difficult of detection; and then, again, chemists are not yet acquainted with any process for the removal of this noxious body from the gas of commerce. All these circumstances give it an importance that it would not otherwise possess. Bisulphuret of carbon is, when pure, an oily-looking liquid that sinks in water. It evolves the unpleasant odour of putrid cabbage, and it boils at a temperature of 106° Fah.; it burns with a blue flame, and its vapour consumes twice and a half its bulk of oxygen, or nearly twelve and a half times its bulk of atmospheric air, producing twice its volume of sulphurous acid, and half its own volume of carbonic acid. This compound is best recognized by burning the gas and collecting the products, in which sulphurous or sulphuric acid will be discovered.

(*e.*) The *tarry matters of inflammable gas* are of a very complex nature; they appear to be held in solution by ammonia, and to be precipitated in the form of dark flakes, when the gas is made to pass through a vessel containing flints moistened with acid. It is very probable that these tarry matters are of an acid nature, and that, in their union with ammonia, they produce compounds that are sufficiently volatile to be suspended in the gas.

(*f.*) The *cyanogen compounds* are not likely to be found in the gas of commerce, for they are readily absorbed by the lime made use of in its purification. Cyanogen, hydrocyanic acid, and sulpho-cyanogen are the most important of these compounds.

The Manufacture of Gas.—In all cases, the destructive distillation of the organic substance which yields the gas is effected in an iron vessel called a retort, which is set in a furnace; and the gaseous products are purified by transmitting them through a series of vessels named condensers and purifiers. The details of the process vary with each particular gas, and consequently it is necessary to describe them under different heads.

Coal Gas.—The *apparatus* which is employed for the manufacture of coal-gas consists, first, of a *retort*, made of iron or clay, set in a furnace in such a manner that it may be heated throughout of a tolerably uniform temperature; an *outlet pipe* ascends from the end of the retort, and terminates in another pipe called the *hydraulic main*. This part of the apparatus is so constructed, that the pipe which delivers the gas from the retort dips down, to the extent of three or four inches, into the liquid matters contained in the hydraulic main. By this means the end of it is sealed or closed with a water-valve, and no gas can run back from the other parts of the apparatus into the retort during the time that the latter is being charged with coal. The *hydraulic main* is a large horizontal pipe, which runs from one end of the building to the other; it receives all the exit-pipes from the retort, and discharges its contents into a series of smaller pipes, which run to and fro or up and down in water or air, and so form a

large cooling surface for the condensation of the liquid matters contained in the raw gas. Here it is that water and tar are deposited; and the apparatus is so constructed that the fluid matters run off, as fast as they are condensed, into a tank which is conveniently placed to receive them. This part of the apparatus is called the *condenser*. From the condenser the gas passes to the *purifiers*, which are vessels charged with lime and other substances that have the power of absorbing the various impurities of coal-gas. To assist the flow of gas through these vessels, an instrument called *an exhauster* is sometimes employed · it is a kind of air-pump worked by a steam-engine, which draws the gas away from the retorts, and so relieves them from that enormous amount of pressure that they would otherwise have to encounter while their gaseous contents are being forced on through the various obstructions that intervene between them and the gasometer. Leaving the purifiers, the gas passes into the large receiver or gasometer, where it is stored.

Materials employed in the Manufacture of Coal-gas.—Of the three varieties of coal known to chemists, the black or bituminous is the only one which is employed to any extent for the manufacture of gas. Lignite or brown coal occurs in too small quantity for this purpose; and glance-coal or anthracite is not sufficiently rich in hydrogen to be of any use to the gas-manufacturer. A small quantity of a peculiar bituminous shale, named boghead coal, has of late been employed in London and elsewhere; but its nature is not sufficiently well determined to enable us to say whether it is regarded as a coal or not.

The varieties of black coal are exceedingly numerous: in a general way, however, they may be divided into four kinds—namely, caking coal, which has the property of melting when it is heated, and so running together; splint coal, which is so named from its splintery fracture; cherry coal, which burns without caking at all; and cannel coal, which is exceedingly hard, compact, and bituminous. The first of these occurs abundantly in the neighbourhood of Newcastle, Northumberland, and Durham; the second in South Wales; and the last in Scotland and in Lancashire. Although these varieties of coal differ very considerably in their value for gas-producing purposes, yet regard must always be paid to the convenience or facility with which they are obtained; and hence we find that, in London, the coals of Newcastle, with certain cannels of Lancashire and Scotland, are employed. In Bristol and its neighbourhood, the coals of Gloucestershire and Wales are used; in Birmingham those of Staffordshire and Wigan; in Leicester, Nottingham, and Derby, the coals of Derbyshire; in Leeds and Sheffield, those of Yorkshire; in Liverpool, Salford, and Manchester, those of Wigan; in Edinburgh and the north of Scotland, the coals are chiefly derived from the Lothians and from Fifeshire; in Glasgow they are obtained from Lesmahago, Kelvinside, Wilsontown, &c.; and in Greenock they are procured from Monkland and Skaterig.

The temperature at which the carbonization of the coal is effected, and the manner in which the heat is applied, have an important influence on the quality of the gas and other products obtained. If the heat is too low, the quantity of gas produced is small, while that of the tar is large: on the contrary, if it is too high, the latter is sacrificed for the generation of the former. In the one case the gas is too rich in hydrocarbons, and in the other it is too poor. In practice, therefore, it is necessary to hit the happy medium; and it is generally thought that Newcastle coal requires a temperature of a dull, red heat (1300° Fah.) for its distillation, and that the richer cannels will bear a temperature of 1800° Fah., or a bright cherry red. The latter is a little above the melting-point of copper, and the former is a little below it.

Some idea may be formed of the relative value of these different kinds of coal by reference to the following table, which exhibits the proportions of volatile matter, coke, and ash produced by each description of coal, as well as the per-centage amount of sulphur contained in the coal, the coke, and the gas. The coals are arranged in the order of their gas-producing properties; and it will be seen that the amount of volatile matter ranges between 23 and 68 per cent., and that the quantity of sulphur contained in the volatile matter is from 1 to 5 per cent.:—

Name of Coal:	Vol. Matt.	Coke.	Ash.	Sulphur in		
				Coal.	Coke.	Vol. Matt.
Boghead	68·4	31·6	22·8	0·53	0·08	0·45
New Brunswick cannel	66·3	33·7	0·6	0·07	0·00	0·07
Kirkness	60·0	40·0	13·5	1·40	0·58	0·82
Capeldrac	54·5	45·5	10·5	0·65	0·20	0·45
Old Wemyss	52·5	47·5	15·1	1·30	0·60	0·70
Staffordshire cannel	50·0	50·0	2·9	1·30	0·52	0·78
Lesmahago	49·6	50·4	9·1	2·25	1·14	1·09
Knightswood	48·5	51·5	2·4	1·10	0·61	0·49
Arniston	45·5	54·5	4·2	1·70	0·95	0·75
Heathern (Stafford)	42·9	57·1	1·8	1·50	0·70	0·80
Ruabon main (N. Wales)	41·5	58·5	1·0	0·85	0·45	0·40
Stavely (Derby)	40·9	59·1	2·7	1·20	0·80	0·40
Radstock (Somerset)	38·3	61·7	3·5	3·10	1·80	1·30
Silkstone (Yorkshire)	38·0	62·0	2·6	1·10	0·60	0·50
Blenkinsopp	38·0	62·0	5·1	1·60	0·80	0·80
Wigan (Lancashire)	37·0	63·0	3·0	1·25	0·60	0·65
Mortomly (S. York)	37·0	63·0	1·6	1·10	0·60	0·50
Elsecar (Yorkshire)	37·0	63·0	1·1	1·20	0·63	0·57
Ramsay (Newcastle)	36·8	63·2	6·6	1·75	0·94	0·81
Hastings' Hartley	36·5	63·4	2·0	0·95	0·50	0·45
South Tyne	36·3	63·7	3·9	2·10	1·10	1·00
West Hartley	35·8	64·2	4·7	1·10	0·60	0·50
Grigleston Cliff	35·6	64·4	1·6	1·40	0·75	0·65
Gosforth	35·0	65·0	1·0	1·10	0·50	0·60
Soap-house Pit	35·0	65·0	0·8	0·75	0·40	0·35
Nailsea (Somerset)	34·9	65·1	3·0	2·85	1·50	1·35
Leverson's Wallsend	34·9	65·1	4·9	1·30	0·65	0·65
Arley (Lancashire)	33·7	66·3	3·6	1·20	0·60	0·60
Lockgelly cannel	33·5	66·5	13·1	0·75	0·25	0·50
Woodthorpe (S. York)	33·1	66·9	10·5	1·20	0·70	0·50
Pelton Main cannel	31·5	68·5	9·4	0·95	0·49	0·46
Washington	31·3	68·7	2·2	1·30	0·67	0·63
Pelaw main	30·3	69·7	2·6	1·20	0·70	0·50
New Pelton	30·2	69·8	1·8	1·10	0·56	0·54
Coal-pit Heath	30·1	69·9	5·8	4·10	2·20	1·90
Garesfield	29·4	7 · 6	1·0	0·85	0·40	0·45
Dean's Primrose	29·3	70·7	2·4	1·40	0·71	0·69
Urpeth	28·7	71·3	1·4	1·00	0·60	0·40
Pelton main	28·4	71·6	1·4	1·10	0·62	0·48
South Peareth	27·8	72·2	1·8	1·20	0·60	0·60
Cumberland	25·6	74·4	1·4	1·10	0·60	0·50
Rhonda (S. Wales)	23·1	76·9	2·1	2·20	1·10	1·10

With regard to the manner in which heat is to be applied, it may be said, that, within certain limits, the more quickly the heat is applied, the greater the quantity and the better the quality of the gas obtained; for too slow a heat generates volatile matter, which condenses in tar; and too quick a heat decomposes the gas, and destroys its illuminating powers. Lastly, it may be remarked, that the duration of the heat ought not to exceed five hours; for at the expiration of that time the gases which are evolved are of little use for illuminating purposes, and the sulphur which is contained in the coke begins to distil over as bisulphuret of carbon, which is a most objectionable impurity.

Purification of Gas.—This is effected in various ways; some of the contrivances being mechanical in their action, and others chemical. When the volatile matters quit the retort, they consist of aqueous vapour, tar, olefiant gas, and other rich hydrocarbons, light carburetted hydrogen, hydrogen, carbonic acid, carbonic oxide, sulphuretted hydrogen, sulphuret of carbon, cyanogen, and ammonia. Only a few of these are required for illuminating purposes, and the rest must be got rid of. Foremost in the order of purification is that which takes place in the hydraulic main. There the most condensable of the empyreumatic vapours are deposited, and they run away into the neighbouring tank as a most fœtid mixture of tar and watery matters. Next to this is the condenser—an apparatus which exposes the gas to a large extent of cooling surface. We have already described the form of the apparatus, and said that it causes the condensation of the liquifiable matters contained in the gas. It precipitates tar, water, and ammonia, in combination with sulphuretted hydrogen, carbonic acid, and cyanogen. In some cases the gas is made to pass through a vessel containing pieces of coke, over which a stream of water is constantly running. The gas enters at the bottom of the vessel, and, having made its way between the fissures of the coke, it escapes at the top. A stream of water runs over the coke in an opposite direction; and thus the gas is, as it were, washed and scrubbed by the two materials with which it is brought into contact. This apparatus is, therefore, very appropriately named a *scrubber*. The only impurities now left in the gas are ammonia, carbonic acid, sulphuretted hydrogen, cyanogen, and bisulphuret of carbon. These can only be removed by the aid of chemical absorbents; and the gas is, therefore, made to pass through a set of vessels which are named, *par excellence*, the purifiers. These contain milk of lime, or lime that has been recently slaked. In the former case it is named a wet-lime purifier, and in the latter a dry. In both cases the gas enters at the bottom of the vessel, and it is either distributed in a stream of small bubbles through the liquid, or else it courses its way between the moist particles of the recently slaked lime. By this contrivance carbonic acid, cyanogen, and sulphuretted hydrogen are extracted from the gas; these combine with the lime and produce a most unpleasant-smelling compound, which is technically termed *blue-billy*. In consequence of the loss of ammonia by this process of purifying, and the disgusting nature of the refuse materials, a number of patents have been taken out at various times for the purification of coal-gas by other means than that of lime alone. The oxides of iron, in various conditions, have been patented by Messrs. Croll, Hills, Laming, and Lowe; the common salts of lead have been patented by Mr. Lowe and Mr. Losh; oxychloride of antimony by Mr. Kirkham; sulphate of iron, with common salt and charcoal, by Mr. Cormack; sulphate of lime and magnesia by Mr. Hills; superphosphate of lime by Mr. Johnson; muriate of lime by Mr. Laming; muriate of manganese by Mr. Croll; and clay by Mr. Bowditch. Indeed, it would appear as if all the refuse matters of the arts had been successively tried and patented, in the hope of their becoming a means of

extracting the impurities from coal-gas. In most cases these substances merely absorb ammonia, and in a few instances they take up sulphuretted hydrogen also. Quitting the purifiers, which are charged with one or more of the preceding compounds, the gas enters the gasometer, and is in the condition in which it is to be supplied to the public.

The products of these operations are more or less valuable in every stage of the process. The coke which is drawn from the retort after the extraction of the gas meets with a ready sale; the ammoniacal liquor which floats upon the tar in the tanks of the condenser and hydraulic main contains enough ammonia to make about sixteen ounces of sulphate, or twelve and a half of carbonate, or eleven and a half of muriate, from every imperial gallon; and as each ton of Newcastle coals produces from ten to twelve gallons of this liquor, there is a large amount of valuable matter generated in the process. The tar, also, is made to give up its wealth by the all-powerful aid of chemistry. As it leaves the manufactory, it is a dark-coloured, heavy liquid, of a most unpleasant odour; but by distillation in rude iron boilers it furnishes naphtha for lamps, dead-oil or creosote for railway timbers, and pitch or asphaltum for a variety of purposes. When the richer varieties of cannel coal have been used for the generation of gas, the tar also contains paraffine, which has already been described; and it likewise yields by distillation an oil which is largely employed for lubricating machinery. Within the last few years a number of patents have been taken out for the management of coal-tar; but as yet we have only begun to have an insight into the nature of the many valuable compounds that are locked up in it. Nevertheless, three classes of bodies have already been discovered in coal-tar; namely, neutral principles, acid substances, and alkaline matters. Among the first are benzole ($C^{12}H^{6}$), toluole ($C^{14}H^{8}$), cumole ($C^{18}H^{12}$), cymole ($C^{20}H^{14}$), naphthaline ($C^{20}H^{8}$), paranaphthaline ($C^{30}H^{12}$), pyrene ($C^{15}H^{6}$), chrysene ($C^{12}H^{6}$), paraffine ($C^{20}H^{21}$), and various liquid hydrocarbons, which have not yet been isolated. Among the acid substances, the most important is the acid of creosote, or carbolic acid ($C^{12}H^{6}O^{2}$); and of the alkaline matters there are pyridine ($C^{10}H^{5}N$), picoline ($C^{12}H^{7}N$), and its homologue, aniline ($C^{12}H^{7}N$), lutidine ($C^{14}H^{9}N$), leucoline ($C^{18}H^{7}N$), a new base ($C^{16}H^{11}N$), and parvoline ($C^{18}H^{13}N$): in addition to which there are, in all probability, other compounds which are isomeric with the preceding. Now the great and interesting fact which has been developed by the study of these compounds is, that they all contain but one element of nitrogen, and that, with one or two exceptions, they rise by regular gradations of two of carbon and two of hydrogen: first we have $10 + 5$, then $12 + 7$, then $14 + 9$, and so on. Besides which, they are all isomeric, or have exactly the same composition with another series of bases called the aniline series. To the chemist these facts are of the greatest importance, not merely because of their individual interest, but because of their influence on the philosophy of science. At one time it was thought that whenever two things differed in their chemical and physical properties, they must be different also in their composition; and when Professor Faraday showed that one of the constituents of the fluid obtained by the condensation of oil-gas was identical, in its chemical composition, with another body (olefiant gas), notwithstanding that it differed from it in all its physical properties, chemists were hardly able to comprehend it; but ere long the fact was recognized as one of the most common occurrences in the whole range of chemistry. And so it is, an examination of the most insignificant of materials will often furnish results that not only affect the ancient landmarks of science, but also open up a new way to the practice of industry and the acquirement of wealth. Who, for example, could have supposed that so disgusting a

liquid as coal-tar—a liquid which a few years since the manufacturers of gas knew not how to dispose of—would, through the golden key of chemistry, be made the means of changing the aspect of chemical science, and of opening up new and profitable branches of industry? Take the crude tar and submit it to distillation at a low temperature—the temperature of boiling water: it yields a light volatile oil, which is commonly called naphtha. This consists in great part of a valuable ethereal liquid, which we have already described under the name of benzole,—a liquid which may be used for burning in lamps, for dissolving resins, and for manufacturing a rich perfume (nitro-benzole), which has the delicious odour of the essential oil of bitter-almonds. By continuing the distillation at a somewhat higher temperature, there passes over an oil which is heavier than water. This is called dead-oil; it contains the naphthaline, paraffine, creosote, and various liquid hydrocarbons, which have not been sufficiently well studied, but which perhaps contain mines of chemical wealth. The dead-oil is largely employed for the preservation of timber, and for lubricating machinery: and lastly, that which remains in the still is sold as asphalt or pitch. As might be expected, there is a difference in the quality of these products, according as the tar is obtained from common Newcastle coal, or from the richer sorts of cannel.

Of the other impurities or products of gas-making, cyanogen is the most important; already it has been extracted from the impure gas, and converted into Prussian blue. It is said that a ton of Newcastle coal will yield enough cyanogen to produce seven pounds of Prussian blue—a quantity that will, at the present market-price of the pigment, almost cover the original cost of the coal.

The mode of obtaining this compound is very simple. When the raw or impure gas is purified by hydrated oxide of iron, according to the patents of Croll, Laming, and Hills, the cyanogen combines with the iron and produces the pigment in question. But when thus made, it is largely contaminated with sulphuret of iron and other impurities. These may be got rid of by washing the mixture with dilute sulphuric or muriatic acid. Or if the iron compound is treated with a solution of potash, it gives up its ferro-cyanogen, and produces prussiate of potash, which is an equally valuable compound.

The following table, which has been constructed from the experiments of Messrs. Barlow and Wright, will afford some idea of the relative proportions of gas, tar, ammoniacal liquor, and coke, furnished per ton by different varieties of coal:—

Coal.	Gas in cubic feet.	Tar in lbs.	Ammo. liquor in lbs.	Coke in lbs.
Pelton main	9650	102	102	1,543
Newcastle cannel	9830	98	60	1,426
Wigan (Ince Hall)	10850	248	162	1,332
Lochgelly cannel	8381	225	340	1,245
Boghead..............	13340	733	0	715
Lesmahago	10779	598	$4\frac{1}{2}$	1,077
Ramsay cannel	9016	295	$6\frac{3}{4}$	1,435
Derbyshire deep main ..	9400	219	179	1,335
Wemyss	10584	210	very little	1,156

Tests for the Impurities in Coal-gas.—Notwithstanding that so much trouble is taken with the purification of coal-gas, yet it is found that a greater or less pro-

portion of the several noxious compounds already described, will escape absorption, and will find their way into the street mains. The most important of these are ammonia, carbonic acid, sulphuretted hydrogen, bisulphuret of carbon, and tarry matter.

The first of these is objectionable from the circumstance that it attacks the fittings, corrodes the meters, and fixes the stop-cocks; besides which, it has the property of holding tar in suspension. Ammonia ought not to exist in coal-gas to a greater extent than one part in about 50,000: that is, 100 cubic feet of gas ought not to contain more than about 3·5 cubic inches, or rather more than half a grain, of ammoniacal vapour. Anything approaching to this quantity may be readily discovered by means of turmeric paper, which is immediately reddened by the impure gas.

The presence of carbonic acid may be known by collecting a bottleful of the gas and shaking it up with a little lime-water; if the impurity be present, the lime-water will be rendered milky. The great objection to carbonic acid is, that it reduces the illuminating power of the gas, and thus lowers its value. Mr. Wright and Mr. Lewis Thompson say, that every one part of carbonic acid in a hundred of gas, reduces its illuminating power to the extent of eight or ten per cent.

Sulphuretted hydrogen may be discovered by a solution of sugar of lead, a little of which ought to be dropped on a strip of white paper, and then held in the gas for a period of not less than ten minutes or a quarter of an hour. If the paper becomes discoloured, sulphuretted hydrogen is present. There are several reasons why this impurity should not exist in coal-gas: it gives to the gas a feted odour; it tarnishes silver, and destroys the beauty of paint; and in the act of burning, it generates a corrosive compound, which acts injuriously on books, linen goods, and other textile fabrics.

Bisulphuret of carbon is not so easily detected, for the gas must be burnt under a platinum rosette, and the products of combustion collected in a vessel containing a little ammonia. Mr. Wright, of the Western Gas Company, has contrived an apparatus for this purpose. Having consumed about twelve cubic feet of gas at the rate of half a cubic foot an hour, it will be found that six or seven ounces of water will have condensed in the receiver. This is to be treated with a solution of nitrate of baryta, that has been rendered acid by a little aqua-fortis. If, in the course of a few hours, a white powder settles to the bottom of the liquid, we may be sure that bisulphuret of carbon was present in the gas; and if we collect the precipitate and weigh it, we shall be able to determine the quantity of impurity present: for every 234 grains of sulphate of baryta, represent 38 grains, or nearly 46 cubic inches, of the vapour of bisulphuret of carbon. By proceeding in this way we find that 100 cubic feet of coal-gas yield from 50 to 300 grains of sulphate of baryta—quantities that represent from 8·1 to 48·6 grains of bisulphuret of carbon. The presence of this impurity in coal-gas is a most serious affair: for it has been shown by Dr. Letheby in several of his Reports to the Corporation of London, that bisulphuret of carbon, in the act of burning and oxydizing, forms sulphuric acid; a great portion of which escapes in a corrosive form, and does enormous damage to every kind of textile fabric. He states that the books in almost every library in the kingdom where gas is used, are falling to pieces from the action of this acid upon the covers; and he makes reference to the libraries of the Athenæum Club-house, the London Institution, the Royal College of Surgeons, the Portico Library at Manchester, and that of the Literary Society at Newcastle-upon-Tyne, for examples of the mischief done. In most of these places, the injury has been so great that a remedy has been called for. This remedy consists in burning the gas in such a

way, that the products of combustion shall be carried away as soon as they are generated.

As regards the quantity of sulphuric acid which is produced in this manner from bisulphuret of carbon, we may say that there is some discrepancy of opinion. Mr. Lewis Thompson states that coal-gas rarely contains less than the one-thousandth of its bulk of bisulphuret of carbon; and if so, 100 cubic feet of the gas can rarely produce less than 298 grains of anhydrous sulphuric acid. In another place he states that he has never obtained less than 40 grains of such acid from 100 cubic feet of gas. On the other hand, Dr. Letheby asserts that he rarely obtains more than 20 grains of the acid. But let the quantity be what it may, it is evident that mischief must arise from its presence, and that the attention of chemists and gas-manufacturers ought to be especially directed to this subject. The quantity of this impurity is small when the gas has been generated at a low heat; but it is large when the temperature of the retort has approached a full red, or when the charges have been kept in beyond five hours. If, therefore, no means can be adopted for the removal of the impurity after it has once been formed, it is manifest that care should be taken not to produce it.

Tarry matter is held in suspension in coal-gas by means of ammonia; consequently, if we pass the gas through a small bottle or tube containing fragments of flint, moistened with dilute sulphuric acid, we shall absorb the ammonia and arrest the tar. When coal-gas, containing much tar in suspension, escapes through the fissures in the street-pipes, it impregnates the soil of the neighbourhood, and gives it a most offensive odour.

Atmospheric air is sometimes present in coal-gas when the exhauster has been doing its work too energetically, or when there have been leakages in the vessels or pipes between the retorts and the exhauster. This is recognized by the blueness or thinness of the flame, and by its low illuminating power.

The Analysis of Coal-gas is rather a complicated undertaking; though a good general idea may be formed of its composition by the following process:—Collect a quantity of gas in a graduated tube over quicksilver; introduce a solution of caustic potash, and agitate it with the gas for some minutes; then allow the tube to stand for a short time, and observe how much carbonic acid has been absorbed. After this has been done, pass up a concentrated solution of pyrogallic acid in potash, or, better still, a small quantity of the powdery crystals of pyrogallic acid itself; shake the tube again, and having allowed it to stand for a few minutes, read off the bulk of oxygen that has disappeared; transfer the gas to another tube over water, and by means of a syringe, or other contrivance, introduce a small quantity of bromine, or of strong solution of bromine; shake the tube for a minute or so, and observe that the bromine is in sufficient quantity to give the gas an orange-red colour; after the lapse of four or five minutes, pass up a solution of potash and shake again. In this way the excess of bromine will be absorbed; and on allowing the tube to stand for a short time, the amount of condensable hydrocarbon may be determined by the loss in bulk. Transfer the gas to another tube, and agitate it with a solution of dichloride of copper in muriatic acid (this is made at once by mixing equal parts of black oxide of copper and recently precipitated copper, with muriatic acid). After a few minutes, the solution is to be withdrawn and the gas washed with potash; the loss in bulk indicates the quantity of carbonic oxide present. Lastly, a portion of the residual gas is to be transferred to an eudiometer, and mixed with about twice its bulk of oxygen; and the mixture is to be fired by the aid of an electric spark. After standing for a few minutes, the loss in bulk is to be observed; a solution of caustic potash is then to be passed up into the gas, and

the absorption of carbonic acid noted. This indicates the amount of light carburetted hydrogen present; and then by subtracting twice this volume from the total amount of diminution caused by the detonation, we obtain a number, two-thirds of which represent the hydrogen of the gas. Lastly, the residual gas, from which the portion for the oxygen experiment was taken, is to be mixed with about four times its bulk of pure chlorine, and exposed for some hours to daylight, or for a moment or two to sunlight, and then washed with potash—the residue is nitrogen. In this way we may obtain an estimate of the proportions of the chief constituents of coal-gas. These, however, vary to the following extent:—

Light carburetted hydrogen	from	35 to 52	per cent.
Hydrogen . . .	,,	25 to 52	,,
Carbonic oxide . .	,,	7 to 9	,,
Carbonic acid . .	,,	0 to 4	,,
Oxygen	,,	0 to 2	,,
Nitrogen . . .	,,	0 to 8	,,
Condensable hydrocarbons	,,	3 to 20	,,

The approximative or commercial value of coal-gas is determined in several ways: thus—

1st. *By means of the Photometer.*—This we have already alluded to when speaking of the general phenomena of light; and it is only necessary to say here that the methods employed are four-fold—namely, Count Rumford's plan, with shadows; Ritchie's, with his instrument that has two reflecting surfaces and a screen in a dark chamber; Wheatstone's, which consists of a mechanical contrivance, whereby a silver bead is made to revolve in such a manner as to produce a geometrical figure with two outlines; and, lastly, the plan usually employed is that of Bunsen's, with a waxed screen and a graduated rod—a description of which has already been given. Some doubt exists as to the kind of illuminating standard which ought to be adopted. Originally the standard was a mould candle of six to the pound; but there are so many objections to its use that it has long been discontinued. Dr. Frankland employs a composite candle, Dr. Fyfe prefers one of wax; and the standard which is specified in most of the Acts of Parliament relating to the subject, is a wax candle of six to the pound, burning at the rate of 120 grains per hour. In general, however, it is found that there are more irregularities with the combustion of wax than with sperm: and, consequently, the latter is now almost always employed. Sometimes the comparison is made with one candle; Dr. Letheby uses two, and Mr. Evans employs three. A jet of gas composed of hydrogen and olefiant gases, mixed in the proportion of nine of the former to one of the latter, has been proposed as a standard of constant value; but the use of it is very inconvenient: and, lastly, Mr. Lewis Thompson has suggested the employment of paraffine.

Finally, it ought to be stated that whenever the quality of gas is estimated by any of these methods, it ought to be consumed from the burner or jet which is best fitted for its combustion. If this is not attended to, a discrepancy to a large extent may arise between two different experimenters. As a rule, common gas requires a larger aperture for combustion than cannel; and high glasses, or chimneys, are apt to lower the illuminating power of the former, and to raise that of the latter. Different experimenters have exhibited different fancies with regard to this part of the subject: for example, Mr. Wright prefers a single jet, the one-eighth of an inch in diameter, for his investigations; Dr. Fyfe makes use of a Winfield or Aberdeen burner; and in London, the burner fixed

by Act of Parliament is an Argand of sixteen holes, with a seven-inch chimney, consuming five cubic feet per hour. There is no doubt, however, that in many cases a fish-tail or a bat's-wing will afford the best light for testing purposes. We append the following table to show how much the character of the burner affects the quality of the results obtained:—

Burner.	Consumption per hour in cubic feet.	Illuminating power.	Illuminating power per foot.
Jet five inches high	1·00	1·00	1·00
Small fish-tail	1·98	2·89	1·45
Large ditto	2·60	4·00	1·53
Small bat's-wing	3·00	4·40	1·46
Large ditto	4·60	8·40	1·87
Argand of forty holes	4·50	7·84	1·74

These results were obtained by Dr. Fyfe with cannel gas; and they show that the large bat's-wing produces a flame that, for equal consumption, is nearly twice as powerful as that with the single jet.

Again, the quantity of gas consumed per hour in the same burner will affect the results; thus—

Burner.	Consumption per hour in cubic ft.	Power of gas per foot.
Argand, with seventy-two holes	7·0	5·57
,, ,, ,,	5·0	6·60
,, ,, ,,	3·3	3.40

From which is is manifest that in ascertaining the illuminating power of gas, great judgment is necessary, both in the selection of the burner and in the rate of consumption, in order to obtain fair and proper results.

2nd. *The Chlorine test* is very much appreciated by Dr. Fyfe. It was originally proposed by Dr. Henry, and in his hands it afforded very accurate results. The objection to the test is its inconvenience; for chlorine takes a long time to prepare, and we are never certain of its being pure. Besides which, it is an unpleasant gas to inhale; and, escaping into the laboratory, it produces the most serious injury to the brass and iron-work of chemical apparatus. The mode of conducting the experiment is this:—A quantity of gas is to be let up into a graduated tube over water; the tube is then to be covered so as to exclude light, and chlorine is to be passed up into it. After standing for ten or fifteen minutes in the dark, the excess of chlorine is to be absorbed by potash, and the amount of absorption read off. The larger the quantity absorbed, the better the gas. This will range from three to twenty per cent. The matters absorbed by the chlorine are the condensable hydrocarbons, which are the illuminating principles of the gas.

3rd. *The Bromine test.*—Many years ago M. Balard showed that bromine had the power of absorbing olefiant gas, and that in this respect, as in most others, it was like chlorine. Lately Mr. Lewis Thompson has taken advantage of this property, and has made it the means of discovering the quality of coal-gas. The reactions of bromine on gas are exactly the same as those of chlorine; but it has an advantage over the latter, in the circumstance that it is much more manageable, that it is more likely to be pure, and that the admission of light does not affect the results. In manipulating with this body we fill a graduated tube, called a Cooper's tube, with gas, and then pour into the shorter leg of the instrument a small quantity of a saturated solution of bromine in water, taking care to use enough to give the gas an orange-red colour. After the

mixture has been shaken, the tube is allowed to stand for about ten minutes, and then the excess of bromine is to be absorbed by means of potash; after which, the amount of absorption is noted. As in the last case, this will range between three and twenty per cent. according to the quality of the gas.

4th. *The Sulphuric Acid test.*—Professor Faraday long since observed, that when concentrated sulphuric acid was brought into contact with the condensable hydrocarbons, it speedily absorbed them. Relying upon this fact, Professor Bunsen has recommended that fuming or anhydrous acid should be employed for the purpose of ascertaining how much of these agents is present in coal-gas. Messrs. Leigh and Frankland have spoken well of the results obtained in this manner; but however successful the process may be in their hands, it is open to many fallacies, and cannot therefore be recommended to the unskilful operator. The mode of experimenting is this:—The gas is to be collected in a graduated tude over mercury; and then a piece of coke or pumice-stone, fastened to a platinum wire and moistened, or rather saturated, with the acid, is to be passed up into the gas; after remaining in contact with it for ten minutes or a quarter of an hour, the coke is to be withdrawn; and as a small quantity of sulphurous acid will have been formed by the action of the coke on the mercury, the gas is to be washed with a little potash, and then the amount of absorption noted. Sulphuric acid does not, however, attack all the hydrocarbons; for it is found that chlorine or bromine will effect a further condensation after the action of the acid. This, with other circumstances, renders the process objectionable.

5th. *The Explosion test.*—Dr. Henry noticed that there was a direct relation between the value of a gas for illuminating purposes, and the quantity of oxygen required to burn it, or of carbonic acid produced thereby. In fact, as the illuminating power of any gas is dependent on the quantity of carbon contained in a given bulk of it, it follows that the products of its combustion must furnish a sure indication of its value. This will be manifest from the following table:—

One volume of		
Marsh gas (CH^2)	2 volumes.	1 volume.
Olefiant gas (C^4H^4)	3 ,,	2 ,,
Superolefiant gas (C^6H^6)	4·5 ,,	3 ,,
Faraday's gas (C^8H^8)	6 ,,	4 ,,
Bicarburetted hyd. (C^6H^3)	7·5 ,,	6 ,,

So that if we mix a known quantity of any gas with about three times its bulk of oxygen, and explode them in an eudiometer by means of electricity, or make them combine by the aid of spongy platinum, as Dr. Henry suggested, the amount of oxygen consumed, and of carbonic acid produced, will serve as indications of the quality of the gas. Dr. Henry found that the best description of coal-gas requires two and a quarter times its bulk of oxygen for combustion, and gives one and a quarter of carbonic acid; while the worst gas of his time took only eight-tenths of its bulk of oxygen, and gave but three-tenths of carbonic acid. The amount of carbonic acid produced is to be determined in the usual way by means of liquor potassæ.

6th. *The Specific Gravity test.*—This is founded on the fact that the rich hydrocarbons are much heavier than the poor ones; for example, if a given bulk of marsh gas, or light carburetted hydrogen, weighs 10 grains, the same bulk of olefiant gas will weigh $17\frac{1}{2}$ grains; and in the case of the other hydrocarbons, the increase in weight is still greater. A knowledge of this fact will enable us to ascertain the value of any

description of gas. We take a glass globe, or flask, fitted air-tight to a stop-cock, and exhaust it with great care, by means of an air-pump; then let in pure and dry hydrogen, and again exhaust. Do this a third or even a fourth time, so as to get the flask as empty of air as possible; then weigh in a delicate balance, and note the amount: pure and dry atmospheric air is now to be admitted, and the flask is to be weighed again. In this manner we ascertain how much of pure dry air, at a temperature of 60° Fah. and a pressure of 30 of the barometer, it contains. When we wish to take the specific gravity of any gas, the globe is to be exhausted as before, then filled with the gas, and weighed; corrections are to be made for any abnormal difference of temperature or pressure; and then we say, as the weight of the vesselful of air is to 1, so is the weight of the gas to its specific gravity. In practice it will be found convenient to have a globe with two stop-cocks, one opposite the other; so that after the first exhaustion and weighing, the globe can be easily filled with gas without the aid of an air-pump, by simply allowing the gas to pass through it for about a quarter of an hour. Mr. Wright has constructed an apparatus which still further simplifies this calculation. It consists of an oiled silk balloon that holds 1000 cubic inches of gas; and as coal-gas is lighter than air, he determines its specific gravity by ascertaining the number of grains which the balloon will carry up. A book that accompanies the apparatus contains instructions for the management of the experiment. The specific gravity of coal-gas ranges between 390 and 750. The former is about the weight of the worst gas from Garefield coals, and the latter of the best from Boghead cannel; a good average of specific gravity is 450. In conducting experiments of this kind, it must be ascertained that the gas does not contain carbonic acid, carbonic oxide, or atmospheric air; for if it does, the specific gravity of the gas is sure to be high, notwithstanding that the illuminating power may be very low.

Before we leave this part of the subject, it may be remarked, that if the specific gravity of a gas is taken before its condensation by bromine, and then again afterwards, the difference in weight will afford a means of ascertaining the specific gravity of the condensed portion; and if this be multiplied by the amount of condensation, we obtain a number that represents very nearly the illuminating power of the gas in sperm candles, as it is usually expressed. For example: a gas of specific gravity 447, has a condensation of 5 per cent., and the residual gas has a specific gravity of 328. Now since 100 cubic inches of the former weigh 13·63 grains, and 95 cubic inches of the latter 9·5 grains, the 5 cubic inches of the condensed portion must have weighed 4·13 grains, and it must have had a specific gravity of 2·7. This, multiplied by 5, the amount of condensation, gives 13·5 as the illuminating power of gas. Experiment showed it to be 14.

7th. *The Durability test.*—Dr. Fyfe, who is an authority in matters of this description, is accustomed to estimate the value of a gas not only by noting its amount of condensation with chlorine, but also by observing the time that it takes to burn a given bulk of it from a jet of a given size, with a flame of a given height. The jet which he employs has an aperture of the one-thirty-third of an inch in diameter, and the flame is four inches in height. The first of these tests he calls the *quality* test, and the latter the *durability*. "I consider," he says, "both of these circumstances absolutely necessary; for though some have insisted only on the one, and others on the other, yet, unless both be taken into account, we do not arrive at the true *value* of the gases, and, consequently, cannot compare one with another for the purpose of illumination." He thinks it possible that two gases may afford by combustion the same amount of light for the same height of flame, but that one may burn away half as fast again as the other;

and, consequently, if no regard is paid to this circumstance, there will be a false estimate of their relative values. His mode of amalgamating these two powers is to multiply the percentage amount of condensation by the durability or time required to burn a cubic foot; and in this way he obtains a number that may be said to represent the true value of the gas. Suppose that one gas, which he takes as a standard, has a condensation of 4·33, and a durability of 50·5 minutes—these multiplied together make 218·7, which may be called the value of the gas. Another gas has a condensation of 7·55, and a durability of 57 minutes; these multiplied together give a value of 430·3. Now if we call the standard number of the former 1, that of the second will be 1·95; and thus we obtain their relative values. The following table is constructed on this principle:—

Gas from	Condensation by chlorine.	Durability of a cubic foot.	Relative value.
English caking-coal (Newcastle)	4·33	50′ 30″	1·00
Peareth and Pelton	6·50	50′ 40″	1·50
Yorkshire Parrot	7·66	52′ 30″	1·85
English cannel (Wigan)	7·55	57′ 0″	1·93
Ramsay Parrot	12·00	62′ 0″	3·40
Midlothian	13·00	60′ 0″	3·56
Lesmahago	17·10	65′ 0″	5·07
Scottish Parrot	15·00	80′ 0″	5·46
Wemyss	19·50	75′ 0″	6·69
Kirkness	20·70	80′ 0″	7·75
Boghead	22·40	81′ 3″	8·32

It will be noticed that when the value of a gas is tested in this manner, it indicates a higher quality than we are accustomed to obtain by means of the photometer; but this Dr. Fyfe regards not as an error in his process, but rather as an evidence that we do not take the best means to burn the gas to the best advantage; and consequently that the illuminating power is, in the case of the richer cannels, a little below its true value.

As a corollary to the preceding, we append a table which shows the quantity of gas furnished by different varieties of coal, together with the specific gravity of the gas, its illuminating power in sperm candles of 120 grains each, its percentage amount of condensation by bromine, and its actual value in sperm candles. This table has been compiled from the results obtained by Mr. Evans, Mr. Thompson, Dr. Letheby, and others.

Coals.	Cubic feet of gas per ton.	Illuminat. power.	Specific gravity.	Condens. by Brom.	Value in grs. of Sperm.
Boghead cannel	15,000	37·75	752	30·0	113,250
Lesmahago No. 1	13,500	27·10	642	16·0	73,170
Wemyss	14,300	24·50	580	14·0	70,070
Lesmahago No. 2	13,200	24·80	618	17·0	65,472
Capeldrae	14,400	19·75	577	16·5	56,880
Armiston	12,600	22·50	626	17·0	56,600
Kirkness	12,800	21·20	562	10·2	54,272
Knightswood	12,200	19·00	550	9·5	50,160
Wigan (Ince Hall)	11,400	20·00	528	11·5	45,600
Ramsay	10,300	21·40	548	12·5	44,084
Pelton cannel	11,500	18·50	520	10·5	42,750
Leverson cannel	11,600	18·00	525	10·0	41,720
Washington cannel	10,500	18·00	500	10·5	37,800

Continuation of Table.

Coals.	Cubic feet of gas per ton.	Illuminat. power.	Specific gravity.	Condens. by Brom.	Value in grs. of Sperm.
Brymbo main	10,500	15·00	540	6·8	31,500
Pelton main	11,000	14·00	430	4·5	30,800
Dean's Primrose	10,500	12·00	430	5·0	28,350"
Washington	10,000	14·00	430	5·0	28,000
Pelaw	11,000	12·75	420	4·5	28,050
Brymbo cannel	6,650	20·00	504	11·5	27,160
Blenkinsopp	9,700	14·00	450	6·0	27,160
Leverson	10,800	12·50	425	4·0	27,000
West Hartley	10,500	12·50	420	4·2	26,250
Hastings' Hartley	10,300	12·50	421	4·3	25,750
New Pelton	10,500	12·00	415	4·8	25,200
Garefield	10,500	11·50	398	3·8	24,150
Gosforth	10,000	12·00	402	4·0	24,000

Oil Gas.—Originally this was the gas most generally in use for illuminating purposes; but the cost of its manufacture was found to be too great for its continued employment.

As far back as the year 1805, Dr. Henry published an account of some experiments which he made on the gas obtained from sperm oil, and he showed that in illuminating power it was the only gas which could compete with olefiant gas. Soon after that Messrs. J. and P. Taylor contrived an apparatus for procuring the gas on a large scale. Their apparatus consisted of a furnace in which there was placed a twisted iron tube, containing fragments of coke. The object of this arrangement was to increase as much as possible the extent of the heating and decomposing surface. When the tube was red-hot, oil was suffered to run into it in a small and continuous stream. In this way the oil was decomposed and resolved into inflammable vapour which escaped, and a fine spongy charcoal which remained behind. The evolved gases were merely washed with water, and then collected in a gasometer. By this process it was found that a gallon of whale-oil yielded about 90 cubic feet of gas, that had a specific gravity of 900, and was about twice as rich in illuminating principles as the best description of coal-gas. Other patentees, as Mr. English, Mr. Booth, and one or two more, followed in the same course, and endeavoured to perfect the process so as to work it on an economical scale; but, notwithstanding that every means were taken to accomplish this, and that the very commonest oils were used for the production of the gas, it was found that it could not at all compete with the cheaper gas obtained from coal: and so the process was abandoned.

Of late, however, an attempt has been made to revive it by a company which has adopted the name of the Vegetable Gas Company; but, as of old, the attempt has not been successful. Nevertheless, it may be said that where coal-gas is very dear, or not to be obtained at all, or where, for sanitary or other purposes, an unusually pure gas is required, then the process of making oil-gas may be practised with advantage. To meet such cases, a small apparatus has been contrived by Mr. Skelton, and a somewhat similar one is sold by Messrs. Burgess and Key of Little Britain. The latter consists of a small cylinder B (Fig. 45), fitted into a furnace C, so as to be made red-hot. A reservoir I, containing oil, or refuse fat, is suspended to the chimney of the furnace G, and when the fat is perfectly liquid it is allowed to drip from a small tap into a syphon

pipe E, whence it runs into the red-hot cylinder and is decomposed. The evolved gases escape by the tube F, and are conveyed by J into a purifier D, which contains water; the delivery tube M dips an inch or so under water in order that the gas may be washed and cooled. The tube K L transmits the gas from the purifier into the gasometer A. The gas which is produced in this manner is of high illuminating power; and it appears from the statements made by the venders of the apparatus, that a pound of kitchen-stuff yields from 10 to 11 cubic feet of gas. Now a pound of this material is 7000 grains; and as the gas produced weighs only about 5000 grains, there is a manifest loss of nearly one-third. This occurs in the form of charcoal, which remains in the retort; and hence the necessity for a frequent cleaning out of this part of the apparatus. Dr. Fyfe states that the loss in his experiments was much greater—that it amounted to nearly one-half of the fat used; and the same remark is also made by Mr. Wright, who has reported upon the comparative economy of the vegetable-gas scheme. The latter gentleman states that for a gallon of 9 lbs. the waste amounts to 2 lbs. 10 oz.

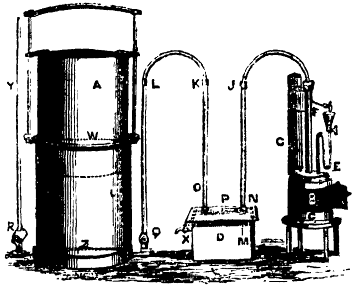

Fig. 45.

The gas which is produced from oil is very heavy; in fact, its specific gravity ranges between 700 and 900. It contains from 30 to 40 per cent. of rich hydrocarbons, which are condensed by chlorine and bromine: of these about 20 per cent. are absorbed by fuming sulphuric acid; 100 volumes of the gas require about 260 volumes of oxygen for their consumption, and they yield 158 volumes of carbonic acid. The durability of the gas, with Dr. Fyfe's four-inch flame from a jet the thirty-third of an inch in diameter, is 68′ 20″; consequently, its value is ten times as great as that of his standard of gas from ordinary Newcastle coal. As might be expected, the illuminating power of such gas is very high: indeed, Mr. Wright has found that it is about four times as great as that of common gas. He states that, with a consumption of one foot and a quarter per hour, it gives the light of twelve sperm candles, each burning at the rate of 120 grains per hour. Our own experiments, however, are not so satisfactory: they are recorded in the following table:—

Burner used.	Consumption per hour.	Illuminating power in sperm candles of 120 grs. per hour.
Small fish-tail	1·50	8
Leslie's Argand	2·25	11
Common Argand, 15 holes	3·50	14
Fine Argand, 70 holes	2·75	12
Winfield Argand	3·50	15

The advantages of this gas are, its freedom from smell; its not containing any sulphur compound; its not producing so much heat as ordinary gas for an equal amount of light; and its easy production in an apparatus which does not occupy much room. Its only disadvantage is its cost; for a shilling's worth of kitchen-stuff will only produce about 40 cubic feet of gas, which will not go farther than six or eight pennyworth of coal-gas.

Portable Gas.—When oil-gas is compressed with a power of from fifteen to twenty atmospheres, it is forced into a very small bulk; and the vessels containing it may be moved about, and placed in any situation where a light is required. A company was formed some years ago for carrying out this object; and they had the gas condensed into globes and cylinders which were placed in vases, columns, and other ornamental devices, so as to be completely hidden from view. Burners were fixed to the apparatus, and the gas was let out by means of a stop-cock of a peculiar construction. In the act of compressing the gas, about one-fifth of its volume underwent condensation into an oily liquid; indeed, a thousand cubic feet of good oil-gas yielded about one gallon of it. This was made the subject of investigation by Professor Faraday. It was a thin oily fluid, lighter than water, sometimes transparent and colourless, at others opalescent, having a red tint by transmitted light, and a green by reflected. Its specific gravity was ·821. This fluid Mr. Faraday found to be a mixture of various hydrocarbons of different degrees of volatility; and taking advantage of this circumstance, he was enabled to separate them. The great bulk of the liquid distilled at a temperature of from 176° to 190°; but a portion also came over at as low a temperature as 98°, and another portion required a heat of about 200° to volatilize it. These liquids consisted of carbon and hydrogen in various proportions. The most volatile was composed of equal atomic parts of carbon and hydrogen (C^4H^4), and a part of the intermediate portion consisted of two of carbon to one of hydrogen (C^6H^3). The others were not sufficiently examined to determine their exact composition, although there was every reason for believing that they were composed, like the first, of equal atomic particles.

M. Couerbe has also examined the liquor which is produced by the compression of resin-gas, and his results are quite as interesting as those of Professor Faraday. He finds that the liquid contains six different fluid hydrocarbons; five of which consist of four atoms of hydrogen and a number of carbon that rises in arithmetical progression from four to eight. The sixth is a compound of twenty-eight atoms of carbon and twenty-two of hydrogen.

Resin Gas.—When it was found that oil could not be profitably used for the manufacture of gas, attention was naturally directed to other and cheaper gas-producing substances. Resin was therefore selected; but it was noticed that when this body was decomposed in the apparatus commonly employed for the generation of oil-gas, it produced a quantity of thick bituminous matter which choked the exit-pipe. This, at first, was regarded as an insurmountable difficulty; but it was overcome by the late Professor Daniell, who contrived an arrangement whereby the gas was delivered from the bottom of the retort by means of a descending pipe. His patent was taken out for this contrivance about thirty years ago, and Messrs. Taylor and Martineau were the first to put it into operation on a large scale. The retort was set in the furnace in the usual manner, and it was charged with coke in order to increase the heating-surface. Across the farther end of the retort there was a diaphragm, or septum, which was open at the top; and beyond this was the communication with the down-going delivery-pipe. The diaphragm served to prevent any of the coke from falling into the exit-tube. The resin was dissolved, or rather liquefied, by the aid of heat, in a small quantity of oil of turpentine, or of the volatile oil produced by the decomposition of the resin in a former process. The proportions were about twenty pounds of resin to a gallon of oil. This mixture was kept hot and fluid, in a reservoir placed over the fire above the retort; and when the contents of the latter were red-hot, it was allowed to run through a

syphon tube, and to drop upon the incandescent coke at the nearest end of the retort. The vapours which were thus produced passed along the whole length of the retort, and were completely decomposed before they escaped over the diaphragm into the descending-pipe. A part of these vapours were liquefied by the cold of the condenser, and they appeared as a limpid volatile oil; the other portion passed on as gas; and, after having been purified by washing with lime-water, it was collected in the gasometer. This process of Daniell's was considered to be very complete, though it has been modified in certain particulars by subsequent patentees: thus, Mr. Richardson has proposed that the resin should be mixed with saw-dust and some alkali, as lime, potash, or soda; and that it should be put into the retort in thin sheet-iron vessels of a cylindrical form. Here the first distillation takes place, and the volatile products are conveyed into other vessels, or retorts, charged with coke, lime, or broken bricks, kept at a red heat. By this means it is thought that more gas, and less volatile oil, will be obtained. Mr. Webster generates the gas in another way. He passes the vapour of coal-naphtha over a bed of heated coke, and thence over a quantity of melted resin. The volatile matters so obtained are made to traverse another vessel filled with incandescent coke, and here they undergo decomposition.

A pound of resin will yield about ten cubic feet of gas, or, more correctly speaking, a hundredweight of resin will furnish from 1000 to 1200 cubic feet of gas, and about three gallons of oil. The gas has a specific gravity of from 660 to 850; and its illuminating power is only a little inferior to that of oil-gas. When it is imperfectly made, it does not contain more than eight or ten per cent. of condensable hydrocarbons; and such a gas was found by Dr. Fyfe to have a durability of fifty-three minutes and twenty seconds—its value therefore is about the same as that of gas from Wigan cannel. As in the case of oil-gas, this illuminating agent does not contain a particle of any sulphur impurity.

The volatile oil which is produced during the manufacture of gas from resin is worth about *7d.* per gallon; and it may be used for dissolving resin, caoutchouc, &c. When it is distilled, it yields about one-seventh of its bulk of a more volatile oil, which is worth *2s. 3d.* a gallon—the residue being of the valve of *5d.* a gallon.

Although the production of gas from resin is not practised in this country, in consequence of the more economical source of it from coals, yet we believe that in many parts of America, where resin or crude turpentine is cheap and abundant, the process is still worked with advantage.

Hydrocarbon Gas.—This is the name given to the mixed gases which are generated from water, and certain substances that are rich in hydrocarbons, as tar, resin, fats, oils, and the better kinds of cannel coal.

Although this description of gas has only very recently been made on the large scale, yet the principles of its manufacture were known and appreciated many years ago. As far back as the year 1830, Mr. Donovan took out a patent for the generation of gas from steam, by passing it over red-hot coke or charcoal; and he subsequently naphthalized it at the burner by means of turpentine or coal-tar. Since that time many improvements have been made in the process; and we may refer to the names of Manby, Val-Marino, Radley, Lowe, White, Croll, Webster, Barlow and Gore, in proof of the number of persons who have taken out patents in this country for the generation and naphthalization of water-gas. In every case the water, or rather the steam, is decomposed by passing it over red-hot coke or charcoal; and it is subsequently naphthalized by mixing it with rich hydrocarbons.

The details of the process vary somewhat with the nature of the materials used. When fat or resin is employed for the production of the gas, the process, as described by Mr. White in his patent, is as follows:—Two retorts, about seven feet long and nine inches in diameter, are set vertically in a furnace so that they may be heated to full redness, or even to an incipient white heat. A flue passes through the centre of each of the retorts, in order that the contents may be thoroughly heated. They are packed full of coke, charcoal, or anthracite, and a few scraps of iron. When the retorts are red-hot, water is allowed to flow through a syphon upon the top of the ignited mass. The steam which is thus generated passes down through the red-hot coke, and is decomposed into hydrogen and carbonic oxide, with more or less of carbonic acid. The gases and vapours thus produced, escape from the bottom of the retorts into two other retorts placed horizontally in the same furnace. These are about six feet long, and are divided into two or more compartments by longitudinal septa which reach nearly to the end. The compartments are filled with coke, chain or coils of iron wire, so as to increase the surface; and into the first of these, tar, fat, or resin is allowed to flow, so as to undergo decomposition. The evolved gases are rapidly carried off and mixed with the gaseous products of the first retort; and after they have passed through a condenser and a lime purifier, they are received into the gasometer. In working the process, the supply of the materials should be so managed, that the gaseous mixture should consist of about four parts of water to six of the other. When resin is used, the proportions of the various materials are one hundredweight of resin, seven and a quarter gallons of resin-oil, fifteen pints of water, a sixth of a bushel of charcoal, and a few ounces of scrap iron. These produce from 1500 to 1600 cubic feet of gas, and about three gallons of oil over and above the quantity originally used. Dr. Frankland has entered into a very detailed examination of this process; and it appears from his report, that a hundredweight of resin, with from thirty to forty pints of water, will yield from 1500 to 1900 cubic feet of gas, and from two to four gallons of oil. The temperature at which the best results are obtained is that of dull redness; for if the heat be carried much above this point, the richer gases are decomposed and evolved into several gases of low illuminating powers. He found that two distinct changes were effected in the water retorts. In one case the steam was decomposed by the red-hot charcoal, and resolved into equal volumes of hydrogen and carbonic *oxide*; in the other, it was converted into two volumes of hydrogen, and one of carbonic *acid*. These mixed gases, together with some undecomposed steam, pass into the resin retort, where they mix with the vapours of the decomposing resin, and pass twice along the length of the red-hot retort. Here the steam is again subjected to decomposition by the agency of the fuliginous matter evolved from the resin. This change is a very important one, for it prevents the accumulation of carbon in the exit-pipe of the retort. If the gas be examined at this stage of its manufacture, it will be found to contain a very large proportion of carbonic acid; and one of the greatest difficulties in the subsequent management of the gas is the removal of this impurity. Ordinary wet lime will only remove a portion of it; and hence Dr. Frankland has recommended the use of caustic soda, which may be produced by the admixture of carbonate of soda with cream of lime.

The gas which is thus produced has a specific gravity of from 600 to 660. It contains from seven to eight per cent. of condensable hydrocarbons; and its illuminating power is about the same as that of ordinary cannel gas. Its composition, both before and after the removal of carbonic acid, is as follows:—

	Ordinary gas.	Pure gas.
Condensable hydrocarbons	7·41	8·13
Light carburetted hydrogen	26·50	29·71
Hydrogen	40·27	43·38
Carbonic oxide	18·55	18·78
Carbonic acid	7·27	0·00
	100·00	100·00

According to Dr. Frankland's report, hydrocarbon gas from steam and resin may be manufactured at from $9\frac{1}{4}d.$ to $1s.\ 1\frac{1}{2}d.$ per 1000 cubic feet. This is irrespective of the cost of the apparatus, or of the charge for wear and tear.

When the gas is made from rich cannel coal, the arrangement of the apparatus is a little different from the preceding. Indeed, the patentee now adopts the following as the general plan of his operations :—

Both the retorts are placed horizontally, and they are divided into two compartments by means of a longitudinal septum that reaches nearly to the end of each. One or more of these, called the water-retorts, are charged with coke; and after being raised to a high temperature, water is allowed to trinkle through a syphon pipe upon the red-hot coke at the outer end of the upper compartment. The steam which is thus generated passes through the ignited contents of the upper compartment, and thence descending behind the septum, it comes forward through the lower. By this means it is exposed to a large surface of red-hot charcoal, and is in great part decomposed and resolved into hydrogen, carbonic oxide, and a little carbonic acid, all of which enter the lower compartment of another retort, which is charged with cannel coal. Here they mix with the various hydrocarbons that are evolved from the coal; and after traversing the retort from one end to the other and back again, they pass into the condenser and wet-lime purifier, and thence into the gasometer. Dr. Frankland states, that by this mode of working, all the carbonic acid which is generated in the water-retort is decomposed by the fuliginous matter of the coal, and converted into twice its bulk of carbonic oxide. It is thought, also, that the water-gases exert a conservative influence on the rich hydrocarbons which are evolved from the coal; and that by sweeping them away as fast as they are produced, and so protecting them from the destructive agency of heat, a much larger quantity of illuminating matter is obtained.

Dr. Frankland has examined the value of this process, as applied to different varieties of cannel coal. He worked with one hundredweight of each of the following coals, and he obtained the following amounts of mixed hydrocarbon gases. The coals were placed in each of the compartments of the second retort, and they were distilled at a low red-heat. The water-gas was obtained in the usual manner:—

Name of coal.	Yield per ton.	Illuminating power of the gas in sperm candles.
Wigan (Ince Hall)	16,120	20·0
Ditto (Balcarres)	15,500	19·1
Newcastle cannel	15,020	18·8
Methyl	26,400	21·0
Lesmahago	29,180	28·7
Boghead	51,720	17·9

The ...inating power was tested in the usual way with a No. 4 fish-tail burner, consumi...e cubic feet per hour, at a pressure of half-an-inch of water; and the candle wa...erm candle, calculated to the amount of 120 grains per hour. According

to Dr. Fyfe's mode of estimating the value of the gas, an average sample has a durability of 43 minutes and 20 seconds, and its amount of condensation by chlorine was 11·44 per cent.; so that its quality was about $2\frac{1}{4}$ that of ordinary gas from Newcastle coal.

Mr. Clegg speaks in the most enthusiastic terms of the value of this process. He says that a ton of Wigan coal yields, under ordinary circumstances, about 10,000 cubic feet of twenty-candle gas; while with the hydrocarbon process it furnishes 16,000 cubic feet of gas of the same quality, and 26,000 cubic feet of twelve-candle gas. A ton of Lesmahago cannel produces in the usual way 10,500 cubic feet of forty-candle gas, but with the hydrocarbon process it will yield 36,000 cubic feet of twenty-candle gas, or 58,000 cubic feet of twelve-candle power; and a ton of Boghead, which generally furnishes about 13,500 cubic feet of forty-candle gas, will by this process give as much as 52,000 cubic feet of twenty-candle gas, or 75,000 of twelve-candle. From which it is manifest that, although there is a comparative reduction of the illuminating power in consequence of the diluting power of the water-gas, yet, on the whole, there is a considerable increase in the amount of illuminating matter. This increase varies from 50 to 100 per cent.; and it is, no doubt, due to the property which water-gas has of suspending the volatile hydrocarbons which are generally condensed in the tar.

Mr. Clegg states that the cost of working the process is not very considerable, for gas of twenty-candle power may be obtained from Wigan coal at the rate of 1*s*. $3\frac{1}{2}$*d*. per 1000, from Lesmahago at $11\frac{3}{4}$*d*., and from Boghead at 11*d*.: besides which, the gas is remarkably free from every kind of sulphur compound. The conclusions at which Dr. Frankland has arrived, after having made a very careful examination of Mr. White's process, are the following:—

1st. That it greatly increases the produce of gas from a given weight of coal, the increase being from 46 to 290 per cent., according to the nature of the material operated upon.

2nd. That it greatly increases the total amount of illuminating power, the increase being from 12 to 108 per cent.

3rd. That it diminishes the quantity of tar formed, by converting it into gases of high illuminating power.

4th. That it affords a means of reducing the illuminating power of gases which could not be profitably burnt alone: and

5th. It may be easily applied to any of the apparatus or modes of working now in use.

In opposition to these conclusions must be placed the results obtained by Messrs. Brande and Cooper, who found that little or no advantage was gained by the process; and Dr. Fyfe, who is much opposed to the whole scheme, states that, when all things are considered, it is a process which ought at once to be abandoned. Mr. Barlow has, however, recently examined the merits of the process; and he believes that, with som few alterations in the way of working, it may be profitably carried out. His suggesti is to collect the water-gas in separate gasometers, and to convey it from them, inst of from the retorts, into the compartments where the coal is distilling. By this m he avoids the injurious action of undecomposed steam, and he effects the decomp of carbonic acid, which is at present so serious an impurity.

Water Gas alone.—Several patents have been taken out, at various t, for the production of gas from water; and the employment of such gas either alon when it is wanted for heating purposes, or in combination with the vapours phtha. Donovan's patent, of 1830, we have already alluded to. M. Floret ha rived a

power for decomposing steam, by means of coke heated to a high temperature in an atmosphere of oxygen. Mr. Paine, of America, says he decomposes water by the aid of electro-magnets; Mr. Adams, of Boston, effects it by the force of a galvanic battery; and Mr. Shepard assists the action by using a salt of ammonia, or a vegetable acid, as oxalic. In Mr. Gillard's process steam is decomposed by passing it over incandescent charcoal, in such a manner as to form hydrogen and carbonic acid; the latter being absorbed in the usual way by means of caustic lime. All these patents, however, are but so many examples of fruitless speculation; and they may be pointed at as illustrations of most unsound chemical knowledge, combined with the very worst kind of practical experience.

As the hydrogen and carbonic oxide produced by either of these processes does not possess the smallest amount of illuminating power, it must be brought up to the required standard, either by passing it through a volatile hydrocarbon, or by burning it in such a way as to make a solid incombustible body white hot. Mr. Gillard adopts the latter contrivance; and his plan is to consume the gas from an Argand burner, over which there is suspended a rosette of platinum wire. The wire becomes intensely heated; and, when the gas is burning at the rate of six and a half cubic feet an hour, the light emitted is about equal to five composite candles, or to that of a fish-tail consuming three feet of ordinary gas per hour.

Wood Gas.—When wood is subjected to distillation in closed iron vessels it evolves a large quantity of inflammable vapour, some of which condenses into a liquid form, while the rest passes off as combustible gas. The liquid consists of water, pyroligneous acid, naphtha, and a complex heavy tar; and the gas is composed of hydrogen, carbonic oxide, carbonic acid, light carburetted hydrogen, and a variable proportion of olefiant gas. When these are consumed in the ordinary way they do not produce much light; but if they are passed through a volatile hydrocarbon, they may be brought up to any degree of illuminating power. It is possible, also, that by certain modifications of the process whereby they are obtained, a sufficient amount of rich hydrocarbons may be generated, to do away with the necessity for subsequent naphthalization. Mr. Hills proposes to mix the gases which are obtained during the manufacture of crude pyroligneous acid, with those which result from the destructive distillation of coal-tar; and Mr. Lowe has taken out a patent for the use of tar, oil, resin, or cannel coal, as a means of giving illuminating power to the gases evolved from sawdust, spent bark, or peat. Other patentees have suggested that the sawdust and tar should be mixed together before they are distilled; but it does not appear that any of these schemes have been successful in practice, or have been able to compete with the more economical mode of obtaining gas from coal. On the Continent, however, where wood is very abundant, and coal scarce, it is frequently more profitable to make gas from the former than from the latter. At Basle, for example, and some other towns of Switzerland, Norway, and Sweden, the process of distilling gas from wood is practised on a very large scale. We are told that the old city of Heilbrown has recently been lighted up with wood-gas; the manufacture of which is under the management of M. Schäufelen, who produces a gas of very good illuminating power. It is said that a fish-tail burner consuming four and a half cubic feet per hour, gives the light of thirteen wax candles; and that one of five cubic feet an hour, produces the light of sixteen candles; while an Argand burner, on Dumas' construction, consuming the same amount of gas, evolves the light of twenty candles. If this be so, it is evident that wood-gas can be obtained of a quality superior to that of ordinary coal-gas.

Peat Gas.—This is nearly of the same composition as the gas evolved from wood; and the collateral products are nearly of the same description and value. Many chemists have, at different times, devoted their attention to this subject; but it is only very recently that precise information has been obtained concerning it. Sir Robert Kane in Ireland, and Dr. Letheby in England, have each reported on the quality of the products generated during the destructive distillation of peat; and from their statements it appears, that 100 parts of peat will furnish from 19 to 40 of charcoal, from 2 to 5 of tar, from 11 to 38 of aqueous matters, and from 25 to 58 of gas. The charcoal is very valuable as a decolorizer and disinfectant; the tar is rich in paraffine and creosote; the watery fluids contain ammonia, acetic acid, and wood-naphtha; and the gases consist of hydrogen, carbonic oxide, carbonic acid, and various hydrocarbons. 1000 parts of peat will yield, on an average, 2·7 of ammonia (equal to 10·4 sulphate), 1·9 acetic acid, 1·4 wood-naphtha, 7·9 volatile oils, 5·5 fixed oils, and 1·4 paraffine. From Dr. Letheby's experiments it appears that a ton of peat will furnish about 13,000 cubic feet of gas, the illuminating power of which is equal to seven standard candles, when the gas is burnt from an Argand that consumes five cubic feet per hour; but the intensity of the light may be brought up to any degree by the usual process of naphthalization. As peat is very abundant, its products valuable, and its gas entirely free from sulphur, it is very probable that it may be used with great advantage as a source of inflammable gas: in fact, a patent has recently been taken out by Mr. Hansor of London, for the manufacture of an illuminating gas from a mixture of 12 parts of peat, 12 of resin, 8 of coal-tar, and 16 of oil. This is effected by distilling the mixture from perforated iron boxes, placed in a furnace heated to a cherry-red; the condensable vapours so produced are then passed through another furnace divided by diaphragms, and heated to a bright red. By this means they are decomposed, and rendered permanently gaseous. The gas so obtained, after having been purified by means of lime, has a density of ·626, and its illuminating power is a little higher than that of common cannel-gas, or it is about twice as great as that of ordinary coal-gas. A fish-tail burner consuming 2·5 cubic feet per hour gives the light of 9·2 standard sperm candles, and an Argand consuming 3·5 feet gives the light of 15·5 candles. One of the great advantages of the gas is its perfect freedom from every kind of sulphur impurity. A company has been formed, under the name of Hansor's Olefiant Gas Company, for carrying the patent into full operation.

Gas from Wine Lees and Grape Skins.—These substances are said to produce a very good gas. One pound weight of either of the materials will furnish seven cubic feet of gas of more than ordinary quality. This fact was demonstrated in the year 1849 by M. Levenair of Bordeaux, and Dr. Berhardt of Paris, in one of their public lectures before the Faculty of Sciences. If the results be uniform, the process affords an easy means of obtaining gas and other valuable products, from a material that has hitherto been used only as a manure; besides which, the residue of the distillation is just as valuable to the wine-grower as the lees themselves.

Gas from Coal Tar.—This liquid has again and again been made the subject of experiment, in the hope that the rich hydrocarbons which it contains might be converted into permanent gases of high illuminating power; but, hitherto, all attempts at effecting this desirable result have signally failed. In the year 1820, Mr. Lowe contrived an apparatus for decomposing coal-tar, and resolving it into permanent gases. It consisted of a furnace with five retorts, three of which were placed below, and two above. These were charged in the ordinary way with coal; and when the carbonization had gone on

for three hours, the tar was allowed to flow through a syphon-pipe into the back part of the upper retorts,—these being the hottest. Here the tar was converted into vapour, and it passed over the incandescent surface of the charge to the front of the retort, where it escaped through the exit-pipe, to the hydraulic main. According to Mr. Lowe, he was enabled to produce, by this arrangement, a maximum quantity of gas of high illuminating power; but, although the process was worked upon a very large scale under the immediate superintendence of the patentee, it did not succeed, and it was soon abandoned. Since that time a number of patents have been taken out for a like purpose; but none have been successful. In some cases the tar has been mixed with small coals; in others with peat; in others with sawdust; and very recently Mr. Way has proposed the use of a porous stone which he saturates with tar. Some have distilled the material at a low heat, others at a moderate temperature, and others at a very high one: so that every species of ingenuity has been exhausted in endeavouring to convert this rich inflammable fluid into a permanent gas.

Other organic substances have been resorted to as a source of gas. M. De Cavaillon has proposed a mixture of bones, suet, oleaginous seeds, spent bark, sawdust, molasses, and small coal. Mr. Booth has claimed the use of resinous woods and oily seeds. Mr. Witty has patented a mixture of vegetable oils, and refuse vegetable matters, such as spent hops, dry peat, or dry sawdust, which he presses into blocks, and distills in earthenware retorts; and then, again, it may be said that Mr. Lowe has obtained a patent for naphthalizing gases from any source, by passing them through a vessel containing coal-naphtha—a process that was suggested many years ago by Dr. Henry of Manchester. Lastly, Mr. Archibald has gone so far as to naphthalize atmospheric air in a somewhat similar way. He first saturates the air with moisture, and then conveys it through benzole, which is the most volatile of the coal-naphthas. He also passes the air through a mixture of one part of benzole, two of alcohol or wood-spirit, and one and a half of water. By this means the air acquires inflammability, and may be burnt from an ordinary gas jet: it may even be stored in gasometers, and distributed in the same way as coal-gas. If the air is not saturated with moisture, so much cold is produced by the volatilization of the benzole as to stop the process of naphthalization; and hence the necessity for adding water to the hydrocarbons.

ON THE APPARATUS REQUIRED FOR THE CONSUMPTION OF GAS.

The Gasmeter.—When gas was first used by the public, it was sold at an annual rent, at so much per burner; but it soon became apparent that this was not a fair mode of dealing with the article, and hence the ingenuity of the mechanic was taxed to contrive a means whereby the gas might be accurately measured. This was accomplished by Mr. Clegg, who in the year 1815 constructed the first meter. In the following year he improved it so far as to obtain a patent for it. At first Mr. Clegg attempted to register the gas by means of two small gasometers, which rose and fell alternately, one receiving the gas while the other was delivering it. But this plan was not successful, and it was, therefore, abandoned for another which constitutes the basis of all the wet-meters that have been contrived since Mr. Clegg's time. It consisted of a drum, which revolved in a chamber half-filled with water. The drum was divided into two compartments, one of which received the gas while the other delivered it. The gas entered through the hollow axis of the instrument; and as the drum revolved and submersed the compart-

ment, the gas was forced through a lateral opening into the outer chamber, and thence to the burners. By means of valvular contrivances, two of which were closed by water and two by springs, the gas was made to flow only in one direction; but as the spring-valves were easily thrown out of order, and the water-valves were of a clumsy form, the instrument was susceptible of very great improvement. Mr. Malam, therefore, in 1819 reconstructed the apparatus. He divided the drum into five compartments—one of which was central, and the others around it (Fig. 46). As in Mr. Clegg's instrument, the gas entered the apparatus through the axis of the drum; but in order that there should be no friction or impediment to its movement, he did away with the stuffing-box in which it worked, and brought the central tube or axis, by means of a rectangular bend, up above the level of the water in the central chamber *d*. He also put aside the clumsy water-valves and the too delicate spring-valves of Clegg's instrument, and adopted a simple contrivance whereby the delivery apertures were made to act of themselves by simply rising above the level of the water. These apertures were in the form of slits, which communicated first between the central chamber and the circumferential ones, and then between the latter and the outer case. On entering the central compartment, the gas escapes through whichever of the first set of slits happens to be above the level of the water. In the figure it is passing from *d* into *a*. This gives a buoyancy to that chamber; and as it rises or floats, it turns the drum round from right to left, causing the gas which is in the upper and descending compartments to escape through their outer slits into the outer chamber, and thence to the burner. It will be noticed that, as the drum revolves, the entrance-slits between the middle and outer chambers are successively carried under the water, and that as soon as this happens, the exit-slits in the circumference of the drum are each in their turn brought out of it. This is shown in the figure as about to occur with compartment *c*, whose entrance-slit is just dipping under the water, while the exit-slit is rising out of it. Since the time of Mr. Malam, other improvements have been effected in the details of this meter; by means of which the revolution of the drum has been made steadier, the amount of friction lessened, and the water kept at one uniform level. Among the names of those who have devoted attention to the subject, are Crosley, Wright, Evans, Hulet, Smith, Paddon and Ford; all of whom have, in some particular or another, perfected the instrument.

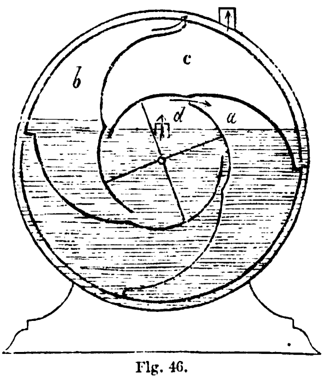

Fig. 46.

Figs. 47 and 48 represent a meter of modern construction, with most of the improvements adopted. The gas passes by the inlet-pipe *a* into the chamber *b*, whence there is a communication by means of a flat valve with the compartment *c*; from this it passes through the bent pipe, forming the axle of the drum, into the compartment *d*, and thence, in the manner already described in Malam's meter, it gets into one or other of the four compartments, and so escapes by an exit-slit into the space formed by the surrounding case. *f* is a ball which floats on the water and keeps the flat valve open. If the water gets below its proper level, the ball falls; and by bringing down the valve, shuts off the

gas. *g* is a tube for passing water into the cistern, and *i* is a waste cistern for receiving the water when it gets above the proper level and flows over. *h* is a syphon-tube for

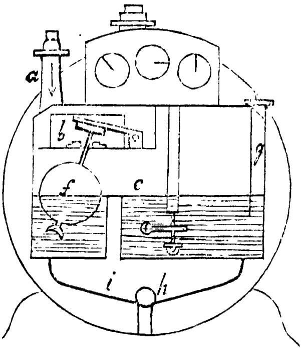

Fig. 47.

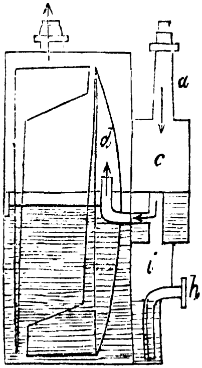

Fig. 48.

drawing off the water which has been added in excess. By a train of wheelwork, the revolutions of the drum are communicated to the hands on the dial-plate; and thus the quantity of gas consumed is registered.

There are two objections to the wet meter, which are insurmountable. These are, that the instrument registers the vapour of water as well as gas; and, secondly, that it is very liable to stop, at an unexpected moment, by the deficiency of water and the sinking of the float. When a meter is placed in a warm situation, the quantity of aqueous vapour that is registered by the instrument, and set down as gas, is very considerable; and if it should so happen that the gas, after passing the meter, has to traverse a cold locality, the aqueous vapour will be recondensed as water, and will cause a flickering of the flame, or even a total occlusion of the pipe.

At one time it was possible for the gas companies to derive an advantage from the overfilling of the water-cistern, whereby the capacity of each measuring chamber was somewhat diminished; and thus a revolution of the drum did not record a proper quantity of gas. It was also possible for the company to be defrauded by a deficiency in the amount of water; but now both of these objections are guarded against by the waste-tube and cistern on the one hand, and by the float-valve on the other.

It will be seen, by an examination of the meter represented in Fig. 46, that, by tilting the meter a little on one side, the gas will pass through the slits of the uppermost chamber without turning the drum at all, and frauds are sometimes committed in this manner; but the experiment is a very dangerous one, and is not likely to be practised by any but the most determined rogue.

The *dry-meter* is a more complicated apparatus, though it consists in all cases of a chamber, or set of chambers, with flexible leather sides. The action is very similar to that of a pair of easy-going bellows; and the movement is communicated to levers and rack-work, which not only register the amount of gas that passes, but, by a set of sliding valves like those of a steam-engine, they also cut off the supply of gas from one chamber, and turn it on into another.

The first dry-meter was patented by Mr. Malam in 1820: it consisted of a set of six bellows placed in a radiating direction around a common centre, the whole being inclosed in an air-tight chamber. These bellows worked successively one after the other, and they communicated their motion to a set of wheels, which served to register the quantity of the gas delivered. This machine was, however, not perfect—it had many radical faults; and hence it did not come into general use. Next after this was the instrument constructed by the Dry-Meter Company. The measuring chamber was formed of leather, which was found to be liable to many objections; for if the meter was used constantly, the leather expanded under the influence of the gas, and so it recorded against the interest of the company; whereas, if it were not used so constantly, it underwent contraction, and then it registered against the consumer: besides which, the valve moved so suddenly from one side to the other as to produce an unsteady flame, and hence the meter was not much patronized. Sullivan's meter, which followed upon this, was open to the same objections; for it consisted of two loose leather diaphragms and a rotatory valve. In 1833, an American, by the name of Berry, patented an instrument which was invented by a person named Bojardin. The meter was a hollow chamber, which had a moveable diaphragm or partition that divided it into two compartments, and, by means of sliding valves, the gas was alternately let in or out of them. In 1836, Bojardin invented a still better machine; and he is looked upon as the originator of the present form of dry-meter. Since that time, Mr. Defries, Mr. Edge, and Mr. Croll have improved the instrument, and brought it into its present condition. Mr. Defries' meter contains three measuring chambers, which are separated from each other by a flexible partition formed of leather, and partially protected from the action of the gas by four triangular metal plates, which almost cover the diaphragm. This flexible partition is raised or depressed by the gas, so as to form a pyramid or a flat surface; and the rise and fall of the partition is communicated to the wheelwork of the apparatus; but, as in all cases where leather enters into the construction of the measuring chamber, the instrument is very liable to register incorrectly. The meter which is manufactured by Messrs. Croll and Glover is said to be free from this objection: its construction will, perhaps, be understood from the following account, taken from Mr. Croll's paper, which was read before the Society of Civil Engineers in 1845. If we imagine a steam-engine measuring its steam by the movements of the piston, we shall have some idea of the principle of the instrument. The steam enters the cylinder over the piston, and forces it down through a certain space; the supply is then cut off, and the action is reversed. Now, suppose the piston to be of a given area, and the distance through which it moves at every stroke to be constant, it can readily be conceived how the actual quantity of steam employed could be indicated and calculated. The meter in question bears a strong resemblance to a double engine: it consists of a cylinder divided by a plate in the centre into two separate cylindrical compartments, which are closed at the opposite ends by metal discs; these discs serve the purpose of pistons, and they are kept in their places by a kind of universal joint adapted to each. The space through which the discs move, and consequently the means of measurement, is governed by metal arms and rods; which space, when once adjusted, cannot vary. To avoid the friction occasioned by a piston working in a cylinder, a band of leather is attached so as to act as a hinge. This folds with the motion of the discs, but it is not in any way concerned in measuring the gas; so that if it were to contract or expand, the registration of the proper quantity of gas would not be affected; for such a change would only decrease or increase the capacity of the hinge, leaving the disc still at

liberty to move through the required space. The leather is also attached in such a manner as to avoid folds, and thus to render it more durable.

Gas-Burners.—Scarcely anything connected with the subject of gas illumination has commanded more attention than the means whereby gas may be burnt to the best advantage; and although the greatest ingenuity has been displayed in the construction of many of the burners which have at different times been invented, yet none of them possess that universal applicability for which they have in most cases been so highly vaunted. The reason of this is obvious: different kinds of gas require different forms of burners, in order to effect perfect combustion. As a rule, it may be stated that the rich cannel gases are best consumed from burners with very fine apertures: while the poorer gases—namely, those which contain less than five or six per cent. of condensable hydrocarbons—are burnt with most advantage from larger apertures. Again, in the former case, provision should be made for a large supply of atmospheric air, as by spreading out the flame by means of an internal button, or by using tall glasses; whereas in the latter case, the very opposite condition should be observed. It is manifest, therefore, that no single burner can be constructed so as to secure both of these requirements; and, consequently, that any burner which is well suited for one kind of gas, is altogether unfit for the other.

Another point of importance to which we may refer in speaking of this subject, is the following:—that when several jets issue from the same burner, and blend together or coalesce, the light is always improved; for it is the property of one jet to assist another by exalting its temperature; and thus a greater heat and a brighter flame are the result of the union,—more light being given out than is the sum of the individual jets. It is on this account that the Argand burner, the fish-tail, the Gaumont, and the Gardner, have obtained preference over many other forms of burners.

Lastly, it may be stated, that in whatever way gas is consumed, the maximum effect, as regards its illuminating power, is always produced by burning the gas just short of its smoking point: for if it be burnt with too much air, the particles of carbon are consumed; and we thus obtain less and less light, until the flame becomes of a pale blue colour. On the other hand, if it be burnt with too small a supply of atmospheric air, the particles of carbon will not be sufficiently consumed, and they will escape as soot,—thereby cooling the flame, and making it of a dingy yellow tint. Our object, therefore, should always be to burn the gas in such a manner that the particles of carbon may be first intensely heated, so as to produce a white light; and then, as they reach the exterior of the flame, they ought to be consumed entirely, so as to avoid the evolution of soot. Of the different varieties of burners now in use, the following are the most important:—

1. *The simple jet* is produced from a burner pierced with a single hole. This mode of consuming gas is not considered to be cleanly or economical; and, except for certain purposes of illumination, as where we wish to produce different kinds of devices, it is rarely employed. Occasionally it is used in the laboratory of the chemist for experiments with the blowpipe, as it is found to give a much hotter and clearer flame with this instrument than any other form of jet. The average consumption of a jet the thirty-third of an inch in diameter, with a flame four inches high, is about one cubic foot per hour. With richer gases the quantity is a little less, and with very poor gases it is somewhat more. As we have already said, Dr. Fyfe prefers a jet of this description for the purpose of estimating the illuminating power of gas; and in a general way it is equal to from one to one and a-half, or two sperm candles.

When it is necessary to produce a greatly diffused light, it may be accomplished by

means of one or more rows of single jets. These may be distributed around the cornice or mouldings of a room, and the effect is remarkably pleasant and agreeable, for there is a flood of light without the least glare or shadow. This plan of illumination has been adopted at the Philharmonic Hall at Liverpool, where about 1000 jets are placed upon the cornice around the room; and Mr. King stated in his evidence before Parliament, that the result is highly satisfactory, and that many persons who see it are disposed to ask—"Whence does this light come from? Is it possible that these small jets are producing this body of light?" The same effect is seen in the streets during the nights of general illumination; and it is also witnessed in the Guildhall of London at the time of the Civic fetes. The only objection to it is its great cost and its liability to evolve smoke; but if these were overcome, and our rooms constructed so as to have a row of lights around a panel in the ceiling, there is no doubt that the effect would be much more pleasing than that which results from our present mode of burning gas; besides which, the panel might be so arranged as to convey away the products of combustion, and thus the effect would also be more salutary.

2. *The Cockspur Burner* is a burner with three or more jets radiating off from it and burning separately. The light from such a burner is only equal to the sum of the individual jets; for as they do not coalesce, they cannot in any way assist each other. It is one of the very worst forms of burner that can be employed. A burner with three jets, consuming three cubic feet per hour of ordinary London gas, gave a light of from five to six candles.

3. *The Fish-tail* or *Union Burner* is so named because of the form of its flame, and because of the manner in which it is produced by the union of two jets. It is formed by drilling two holes at an inclination or angle of about 60°. The jets are directed into each other; and as they coalesce, they spread out so as to produce a flat sheet of flame of the form of a fish-tail: by this means the intensity of the light is greatly increased. The holes are drilled large or small, according to the quality of the gas to be employed. In the case of cannel gas, the holes are small; and for common London gas they are rather large. The former are known by the name of Lancashire or Scotch fish-tails, and the latter as London jets. Each sort is numbered 1, 2, 3, or 4, according to the size of the holes; and these numbers are indicated by means of little rings turned on the body of the jet. No. 1 is the smallest. These burners consume from two to four cubic feet of gas per hour; and with cannel gas they give the light of from eight to fourteen candles, and with common gas of from four to ten.

4. *Johnson's Burner* is a fish-tail with four converging holes; and there is an aperture through the centre of the burner for the admission of atmospheric air into the flame. We have no knowledge of the economic value of this burner.

5. *Billow's* or *Gardner's Burner.*—This is a combination of two fish-tail or bat's-wing burners, arranged so as to produce one flat flame (Fig. 49). The flames impinge on each other, and thus increase the illuminating power by about thirty per cent. These burners are usually constructed of two fish-tails; and occasionally, for experimental purposes, they are attached to a hinge-joint, so that the flames may be burnt separately or together. As in the case of the ordinary fish-tails, they are numbered 1, 2, 3 and 4. No. 1 consumes about three cubic feet per hour, and No. 4 about five.

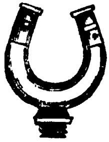

Fig. 49.

6. *The Bat's-wing Burner* is so named on account of the shape of the flame. It is one of the oldest forms of gas-burners; it is constructed with a slit instead of two holes for

the exit of gas; and the flame is broader and not so high as the fish-tail. These burners are easily managed, and on this account they are generally supplied to the public lamps. They burn from three to five cubic feet per hour; and with a consumption of four cubic feet per hour they give the light of about nine sperm candles of standard quality.

7. *The Gaumont Burner* is a bat's-wing burner with two or three slits, instead of one. By means of this contrivance there are two or three flames amalgamated into one; and, as is always the case under these circumstances, the total amount of light is increased. A Gaumont which consumes three cubic feet per hour, gives the light of seven sperm candles.

8. *The Sun Burner* is a cluster of fish-tail burners, usually nine in number, placed around a common axis, and spreading out in a horizontal direction, so as to produce the figure of a flower or the sun. This burner is so constructed, that the products of combustion are carried out of the room by means of a ventilating funnel and tube placed immediately over it; and the air which supplies the flames is made to descend along the ventilating tube, and thus to become very hot before it reaches the burner. By this arrangement there is a great saving of gas. In most cases the sun-burner consists of seven clusters of nine fish-tails each. The burners are supplied with gas by a descending-pipe, which branches to each cluster; and surrounding the whole is a sheet-iron cone, with a tube attached to the top, for carrying off the products of combustion. In this tube there is placed a butterfly-valve, for the purpose of regulating the current of air, so that the draught may not be too great, and the lights may burn in a horizontal direction. Around the cone are placed three other sheet-iron cases, which not only serve for ventilation and for the supply of air to the burners, but also insulate the inner cone, and by their cooling effect, prevent the intense heat of the latter from being communicated to the woodwork of the ceiling. These cylinders are not connected to each other, or to the cone, and, therefore, distinct currents of air pass between each of them; and such is the cooling effect of these currents, that, while the cone is red-hot, the two outside cases are of the same temperature as the atmosphere of the room. On the upper part of these cylinders there is an inverted cone, with a pipe passing through the ceiling and roof, and protected on the outside by a wind-guard which allows the hot air and products of combustion to escape. By this contrivance the gas is consumed in a very heated atmosphere, and thus there is less necessity for combustion in order to obtain a given amount of light; for, in the generality of cases, a large portion of the gas consumed is employed in raising the air to the temperature necessary for sustaining the ignition of the small particles of carbon contained in the flame. It has been stated by Mr. Edwards of Liverpool that the burners, in this position, do not consume more than half the usual amount of gas; besides which, the intensity of the light is very great. He says that the cost of lighting the sun-burner which is placed over the orchestra of the Philharmonic Hall at Liverpool, is 7½*d.* per hour. This burner contains a hundred and seventy-one small-sized fish-tails, which, under ordinary circumstances, would cost about 1*s.* 1*d.* per hour.

9. *The Common Argand Burner* produces a flame which is exactly like that of an ordinary Argand oil-lamp. The burner consists of a circular disc of iron, pierced with a number of holes. It is hollow in the middle for the purpose of allowing a supply of air to the interior of the flame; and the jets of gas coalesce, so as to form a hollow cylindrical flame. A glass chimney is placed around the burner in order that the supply of atmospheric air may be copious and steady. The number of holes or jets varies from ten to thirty for ordinary gas, and from thirty to ninety for cannel. In the former

case the holes are comparatively large, and in the latter they are very small. When common gas is consumed from an Argand burner, the chimney ought not to be above seven inches in height; but when cannel-gas is burnt, it may be increased to nine or ten inches. If the chimney be too high, the supply of atmospheric air is too great, and the gas is overburnt; whereas, if it be too low, the supply is not sufficient, and then the gas smokes: in either case the intensity of the light is diminished. For ordinary London gas, a burner with fifteen holes, and a seven-inch chimney, is considered to be the best. Such a burner will consume about five cubic feet of gas per hour, and will give the light of fifteen sperm candles.

Several patents have been taken out during the last few years for improvements in this form of burner: they have chiefly been directed to the lessening of the shadow which is cast by the ring and body of the apparatus. Of all these, Platow's is the most important. His burner consists of a mere ring perforated with holes.

10. *The Argand with a Button or Deflecting Disc.*—This form of burner has received various names, according as it has been modified by different patentees. It is called the Winfield burner, Young's burner, Guize's burner, and the Aberdeen burner. The button or disc is composed of copper or iron, and it is placed in the centre of the flame a little above the level of the burner. It acts as a break to the inner current of air, and deflects it outwards so as to enlarge the upper part of the flame, and to give it the form of a tulip (Fig. 50). This kind of burner is only suited for the richer kinds of gas, as cannel gas and naphthalized gas. In some cases the air is deflected to the outside as well as inside of the flame. This is the principle of Guize's burner, and the deflection is effected below the button by means of a bend or constriction in the glass chimney, or else by the aid of a metal cone like that of the solar lamp. In Young's burner there is a series of discs placed one above the other, the discs being successively larger and larger from below upwards; by this means the air suffers a series of deflections, and causes the flame to be most vivid. A burner of this description is particularly well suited for the combustion of very rich cannel gas.

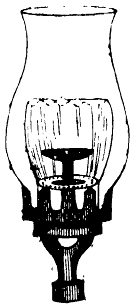

Fig. 50.

11. *The Argand Burner with two or more Rings of Flame, one within the other.*—This is the principle of the Boccius burner; and, from the circumstance that one flame always assists another in promoting the combustion of another, the light from this burner is very considerable. Mr. Carter has obtained a patent for a burner of this description, modified somewhat in its form so as to provide for a due supply of atmospheric air, and also to carry off the products of combustion. The burner consists of a series of Argand flames concentric to each other, with only just so much space between the rings as will serve for the transmission of the necessary quantity of atmospheric air; and over the flames there is placed a conical chimney which carries away the products of combustion. In the concentric burners hitherto used, the object has been simply to obtain the effect of two or more concentric flames, without having due regard to the proper and uniform supply of air to each flame. The consequence of this is, that great and unnecessary quantities

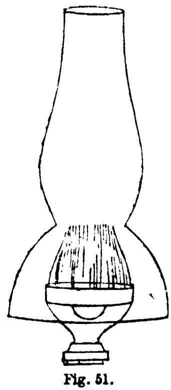

Fig. 51.

of air enter such burners; and the flame is thereby cooled much below the temperature requisite for the perfect combustion of the gas. On this account the intensity of the light is very much below what it ought to be. In Mr. Carter's burners this objection is overcome; for the space between the rings is properly graduated, and the current of air is made to compress the flame and blow in upon it by means of a contraction in the glass chimney—the point of contraction being at such a height above the burner as to produce a bright and steady flame (Fig. 51). The ventilating-shaft is placed over the burner, and communicates above the ceiling with the chimney. It consists of a funnel, and a tube which may be either of metal or glass. These are arranged so as to regulate the supply of air to the flames, and they are enclosed in a chandelier of glass pendants.

12. *An Argand with a Jet of Gas within it.*—This form of burner has been patented by Mr. Billows, who describes it as an ordinary Argand, having a central tube with a single jet, which burns within the hollow of the flame: and, instead of the ring being perforated with a number of holes for the issue of gas, as is usually the case, the ring is contrived with a circular slit, so that there is a continuous sheet of flame in a cylindrical form.

13. *Leslie's Argand* is the very reverse of the last; for the principle on which it is constructed is to allow a current of air to pass up between each of the jets, and so to destroy, to a certain extent, the continuity of the flame. This is effected by a number of small tubes, which rise to the height of an inch or so above the ring which supports them. These tubes are made to converge a little as they advance upwards, and thus they form a truncated cone (Fig. 52). The glasses are constricted, so as to deflect the air into the flame; and they are of different heights, in order that they may be suited to different amounts of consumption. These burners are very well suited for the combustion of cannel gas, but they destroy the light of common gas by over-burning it. The flame should be always managed so as to reach nearly to the top of the glass: for if it passes above it, soot is deposited; and if it does not reach almost to the level of the glass, the gas is over-burnt and light is sacrificed.

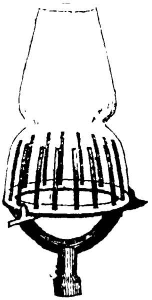

Fig. 52.

14. *The Pinnacle Burner*, of Messrs. Baldwin and Neal, is constructed on somewhat the same principle as the last, only the tubes are very short—they are, in fact, but mere nipples on the top of the ring, and the glass is not constricted (Fig. 53).

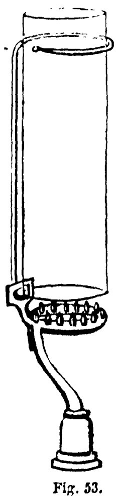

Fig. 53.

Many other varieties of gas-burners have been invented; and as the orifices of the jets are very liable to corrosion from the ammonia and sulphur contained in the gas, Mr. Hallen has proposed that clay or porcelain nozzles should be employed.

The relative values of the several kinds of burners, as employed in the combustion of ordinary London gas, as well as that from cannel coal, may be perceived from the following table. The value is represented as per cubic foot in sperm candles of 120 grains consumption:—

Burner.	Cannel gas: candles per foot.	Common gas: candles per foot.
Single jet	2·6	1·5
Cockspur	3·0	1·5
Fish-tail, No. 1	3·0	1·9
,, No. 2	3·6	2·0
,, No. 3	4·0	2·3
,, No. 4	4·3	2·4
Bat's-wing, nearly the same as fish-tail.		
Leslie, with 28 tubes	3·6	2·7
Gaumont	4·0	2·3
Common Argand, 15 holes	4·0	2·8
Bynner's 28 ,,	4·0	3·2
Platow's 16 ,,	4·2	2·9
Guize 26 ,,	4·2	3·0
Winfield 58 ,,	4·3	2·8
Billow's, with 3 slits	4·1	2·6

From this it will be seen that the simple jet is the worst kind of burner that can be used for the consumption of gas; next come the smaller-sized fish-tails, then the bat-wings, and lastly the Argands. The Gaumont or double fish-tail, and the Billow's or compound bat's-wing, are also very good burners. But it will be evident from the preceding table, that the burner which is best suited for common gas is not always the one that can be most economically employed for cannel.

The pressure at which gas ought to be consumed is another point of considerable importance: for if the amount of pressure be high, the gas will burn with a roaring noise, and will be consumed wastefully; whereas if it be low, the fish-tail and bat's-wing flames will not be sufficiently spread out, and the light will be dim and smoky. Dr. Letheby states in his Ninth Report to the Corporation of London, that gas ought to be delivered to the public at not less than half an inch of water pressure; and it may be said that in practice this is found to be the best pressure at which gas can be consumed.

Again, it is a matter of importance that the pressure at which gas is supplied to the burner should be as uniform as possible; for if at one time the pressure is great, and at another low, the burner requires constant attention, in order that the flame shall be of one uniform height.

Experiments have been made to determine the rate at which gas burns under different pressures; and as the results are somewhat important, they are tabulated below. In a general way, it may be said, that by doubling the amount of pressure, we increase the consumption of gas by about half.

Burner.	Pressure in inch of water.	Consumption per hour.
Single jet	0·30	2·6 cubic feet.
,, ,,	0·60	3.9 ,, ,,
,, ,,	1·20	5·2 ,, ,,
Small fish-tail	0·34	1·4 ,, ,,
,, ,, ,,	0·77	2·2 ,, ,,
Large ,, ,,	0·48	2·3 ,, ,,
,, ,, ,,	0·97	3·3 ,, ,,
Large bat's-wing	0·70	3·1 ,, ,,
,, ,, ,,	1·40	4·5 ,, ,,

Dr. Fyfe has also observed that there are certain constant relations between *the specific gravity* of a gas (that is, its goodness) and *the pressure* at which it is burnt, and *the time* required to consume it—that is, provided we use a jet of a given size, and take care that the flame is of a given height. The jet which he prefers, is one having a hole the fortieth of an inch in diameter; and the height of the flame should be five inches. These relations are as follow:—

1st. The consumption of gas in a given time is as the square root of the pressure; and, consequently, the time required for the consumption of equal volumes, is inversely as the square root of the pressures.

2nd. The specific gravity of the gas is also inversely as the square root of the pressures.

So that if we determine, by experiment, what time it takes for a given volume of gas, of known specific gravity, to burn from a jet of the given size, with a flame of the given height, we are then in a condition to tell the specific gravity, or the rate of consumption, of any other gas, provided it be burnt under the same circumstances, and we observe the pressure. This will be manifest from the following table:—

Pressure in inch of water.	Consumption per hour.	Specific gravity.
0·6	0·67	·841
0·7	0·72	·779
0·8	0·77	·729
0·9	0·81	·687
1·0	0·86	·652
1·1	0·90	·622
1·2	0·94	·595
1·3	0·98	·572
1·4	1·02	·551
1·5	1·05	·532
1·6	1·09	·515
1·7	1·12	·500
1·8	1·15	·486
1·9	1·18	·472
2·0	1·21	·461

By means of this table, we are able to determine the rate at which gas is burning, or its specific gravity, by merely observing the pressure which is necessary to obtain a flame of the given height. In conducting the experiment, the pressure-gauge must of course be on the jet side of the tap. Dr. Fyfe suggests that we may, by operating in this manner, do away with the necessity for a meter or a photometer, or both, and that we may arrive at results which are approximatively correct. Of course it must be understood that the gas is of the usual quality, free from carbonic acid and atmospheric air.

When coal-gas is supplied to the consumer at pressures which are variable, or inconveniently large, the difficulty may be overcome by using instruments which are called *governors* or *regulators*. In some small towns the only means that are adopted for regulating the pressure of gas, is that of taking off or putting on the weights of the gasometer. But as this is a very inconvenient, and at the same time ineffective mode of regulating the supply of gas, it is usual in all large manufactories to employ a governor at the works themselves. This is a small gasometer working very easily and truly in a

tank or cistern of water. It is furnished with two pipes—one for the inlet of the gas and the other for the outlet. The former is situated in the centre of the apparatus; and it is provided with a conical or parabolic valve. This consists of a conical or parabolic cavity or socket, in which a solid plug of the same form fits very accurately. The plug is attached to the top of the gasometer, and the inlet-pipe containing the socket is fixed to the bottom of the instrument: consequently, as the gas-holder rises and falls, it carries the plug with it, and so opens and shuts the conical valve; by which means the supply of gas is regulated. Any amount of pressure short of that at which the gas is received into the apparatus, may be communicated to the delivery-pipe by means of weights that are put upon the top of the gas-holder; and as the governor is always placed between the large gasometer at the works, and the pipes constituting the street mains, the pressure of the gas in the latter is regulated in a tolerably effective manner. It would be very effective, indeed, if it were not that there is a rapid taking off of pressure from the gas in the mains by the turning on of the consumers' lights. This causes such a sudden and enormous abstraction of gas from the mains, that the pressure immediately falls. For example:—In the early part of the evening, just before the lights of the neighbouring shops are turned on, the gas in the mains has a pressure of from one inch to one inch and a-half of water; but as soon as the supply is opened to the several burners of the locality, the pressure immediately drops to less than half an inch of water; and then again, when the lights are in great part turned off, the pressure quickly rises. This occasions much inconvenience to those who are burning gas in an economical manner; for it demands constant attention to keep the flame at its proper level. To remedy this, a smaller kind of governor is often used by the consumer himself. There are various forms of this instrument, but they are nearly always constructed on the same principle as the large one. They contain a valvular aperture, which opens or shuts according to the supply at the burners. This is effected either by the plug and socket already described, or by means of a disc which rises and falls over a small aperture. The first mode of constructing the governor was patented by Mr. Clegg, as long ago as the year 1815, and it constitutes the principle of most of the wet governors of the present time. Of these, one of the simplest in its construction is that manufactured by Mr. Glover. It is represented in Fig. 54. *f* is the connection by which it is fixed to the meter, and the gas passes through the pipe *g* into the gasometer *d*. At the top of the pipe *g*, there is a conical valve *i*, *h*, the plug of which is fixed to the top of the little gasometer *d*; and, consequently, as the gas enters the latter and lifts it out of the water in which it floats, the valve is closed. *p q* is a rod fixed to the top of the gasometer, and projecting beyond the cover of the instrument; it serves for holding weights, *r r*, which press down the gasometer, and communicate any amount of pressure that may be required

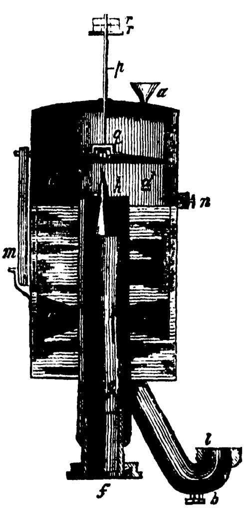

Fig. 54.

The gas escapes from *d*, through the outlet pipe *l*—water is poured into the apparatus through the funnel *a*, and it is kept at a proper level by the tube and plug *n*, while the gauge *m* enables the observer to note at what height the level of the water stands. Lastly, there is a plug at *b* to draw off any water which may happen to spill over or condense in the outlet pipe *l*. When the gas enters the chamber *d*, it lifts the gasometer, and with it the plug *h*, so that the aperture *i* is then closed. Directly the gas is let out from the chamber to the burners by the delivery tube *l*, the weights *r r* on the rod *p* immediately depress the gasometer, and then the valve is again opened for the entry of more gas; and thus, according to the weights at *r r*, and the supply to the burners, will the gasometer be rising or falling, and so keeping up a uniform supply and pressure.

In the governor which has been constructed by Mr. King of Liverpool, the gasometer is made rather heavy, and it is suspended to one arm of a very nicely moving beam, like that of a pair of scales, while weights are attached to the other arm so as to regulate the degree of pressure.

In Mutrel's governor the beam is within the body of the instrument (Fig. 55), and the gasometer floats in an exterior vessel or chamber of water, while the pressure is regulated by a weight *a*, which slides backwards and forwards on an external beam.

The American regulator, invented by Dr. Kidders, is constructed on the same principle, though the gasometer floats in quicksilver instead of water, and the valve is discoid in lieu of being conical.

The governor which is patented by Messrs. Hulett and Paddon contains the beam within a horizontal tube, and the weight floats upon the surface of quicksilver, so that

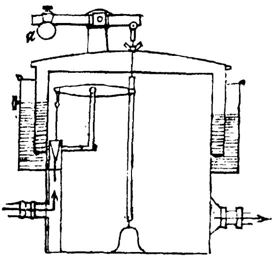

Fig. 55.

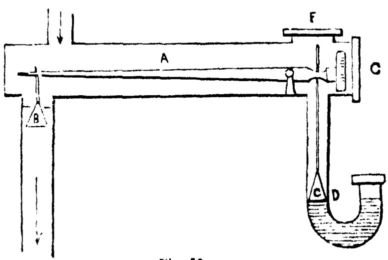

Fig. 56.

the pressure of the gas may be made to regulate itself. This instrument is shown in Fig. 56; and it will be seen that when the gas from the main enters the chamber A, it will by its pressure force down the surface of the quicksilver at D, and this will cause the plug or weight C to fall, and consequently the valve B at the other end of the beam to rise and so to close the aperture which transmits the gas to the burners. There are caps at F and G to be removed when the counterpoise is to be regulated to any other pressure.

Mr. Poole has taken out a patent for the use of a succession of small governors, in order that the supply may be still better regulated; and Mr. Platow has constructed a dry governor which works without any fluid at all. Lastly, Mr. Biddel has contrived a burner which regulates itself. It consists of an ordinary Argand, with a compound bar of brass and iron. The bar is formed of a brass tube with a central rod of iron; the latter is attached to the top of the former, and plays freely within it. When the burner

is lighted, the bar stands up in the middle or hollow of the flame; and as these metals expand unequally for the same temperature, the motion of the longer rod is communicated to a small lever so as to move a plug which opens or shuts the aperture that delivers the gas. The temperature of the flame is thus made available as a means of regulating the supply of gas, and so of keeping the flame at one uniform height. After the burner has been once set, so as to produce the necessary amount of light, any increase in the supply of gas will immediately increase the size of the flame, and this will cause the bar to expand and act on the plug so as to shut off a portion of the gas. On the contrary, if the supply is not sufficient, the bar contracts, and then the aperture is opened.

ON THE GENERAL MANAGEMENT OF GAS, VENTILATION, &c.

General Management of Gas.—On the Continent, the government or municipal authorities enforce certain regulations for the management and distribution of gas. In Hamburg, for instance, the gas-fitters are obliged to perform their work in a certain manner: they must use tubes of wrought-iron, brass, or copper; and in cases where these are not very easily adapted, tubes of drawn-tin may be employed. The joinings must be made in a durable and solid manner, either by means of sockets ground in and cemented with iron cement, or by screwing up, or by soldering. Any other mode of connection is forbidden. The tubes must be placed in localities where they are accessible, so that in case of leakage the mischief may be easily remedied. The cocks must be arranged in such a manner that they only make the fourth part of a turn, and they must be fixed so as not to be removeable from the barrel. The gas-meters are to be furnished by the gas company, and examined and stamped by the adjusting commissioner. In case of fire, all the tubes of one inch or more in diameter should have a stop-cock, so that they may be shut off from the main-pipe. No one is allowed to make use of his gas-fittings until the gas-fitter has tested their soundness, by means of a pressure of one inch of mercury or fourteen inches of water. All the gas-fitters are sworn to adhere to these instructions; and in case of any damage resulting from negligence on the part of the fitter, private persons are entitled to enforce their claims against the gas-fitter before a civil court of justice.

In a supplemental notice attached to the contract made between the English Gas Company in Paris and its consumers, the following regulations are recommended:—"To prevent any inconvenience in the use of gas, it is requisite that the burners should not allow any gas to escape in an unconsumed or imperfectly-consumed state. This result is obtained by maintaining the flame at a moderate height—three inches and a quarter at most, and confining it within a glass chimney of eight inches in height. The rooms lighted should be carefully ventilated, even during the cessation of lighting, by openings in the ceiling, through which the gas and its burnt products may escape. The plugs of the cocks should be greased from time to time, so as to prevent oxydation, and to facilitate their working.

"In *lighting* the gas, it is essential to open, in the first instance, the maincock, and then to apply the light successively to each burner at the moment of opening its cock, so as to prevent the escape of any unconsumed gas.

"In *extinguishing the light*, it is better first to close the maincock, and then to shut off the taps at each of the burners. Whenever a smell of gas indicates that there is a

leak in the pipes, the doors and windows should be opened, so as to cause a current of air through the room; and the maintap should be closed. The consumer should abstain from searching for any leak with a light, but he should rather give notice to the company and the gas-fitter. In case, whether by imprudence or by accident, the escape shall have been ignited, the best means of extinguishing it is to cover the aperture with a wet cloth."

These rules are of great importance, for very serious accidents have resulted from the explosion of gas mixed with atmospheric air. A few years ago—namely, in the month of August, 1848—a fearful disaster of this description occurred in Albany Street. The gas accumulated in the shop for a very short time only—in fact, it had been escaping no longer than one hour and twenty minutes from a crack in the meter; the area of the room was about 1620 cubic feet; but when the gaseous mixture ignited, it blew out the entire front of the premises, carrying two persons through a window into a back yard, and forcing another by the violence of the shock on to the pavement on the opposite side of the street, where she was picked up dead. For more than a quarter of a mile on each side of the house the effects of the explosion were severely felt, and the glass in most of the windows of the neighbourhood was shattered. But the most extraordinary evidence of its enormous power was exhibited in the condition of the premises which immediately faced the house that was destroyed: in one of these the iron railings around the area were snapped asunder, and in another a part of the roof and back windows were carried to a distance of from 200 to 300 yards; besides which, the pavement was torn up for a considerable length. According to the official reports which were made to the insurance offices, it appears that 103 houses were injured by the explosion, and that the damage done amounted to £20,000.

Another accident of a similar kind occurred in the month of July, 1850, at the Ilford toll-gate, whereby three persons were severely injured. The space in which the gas accumulated had an area of eighty cubic feet, and the gas had been escaping into it at the rate of forty cubic feet an hour for a period of fifteen minutes. A piece of lighted paper was incautiously introduced for the purpose of seeing where the leak was, and the mixture immediately exploded, breaking up the flooring of the room, blowing out the window, and knocking down a large portion of the front and partition walls of the building. These accidents were made the subject of scientific investigation, and reports were furnished to the journals by Dr. Arnott, Dr. Letheby, and Dr. Alfred Taylor. In speaking of the latter, Dr. Letheby says—"It is difficult to form an estimate of the total explosive force exerted by the gas on this occasion; but I am led to think that it was probably equal to about twenty tons—for when a column of mixed gas, consisting of one part of coal-gas and seven of air (the proportion in this case), is fired, it expands to about five times its bulk, and exerts a pressure of about four pounds on the square inch." In the report given by Dr. Arnott on the explosion in Albany Street, it is stated that the strongest explosive mixture consists of one part gas and ten atmospheric air, the expansion being in that case tenfold; and in a report furnished by M. Tourdes on the explosion which took place at Strasburg in 1848, it is stated, that the greatest force results from a mixture of one part of gas and eleven of air. These discrepancies doubtless arise from the variations in the composition of coal-gas; but it may be stated, in a general way, that from seven to eleven parts of air to one of gas constitute the most dangerous proportions; for if the gas or the air be much in excess over these, the force of the explosion is very much diminished. This is exemplified in a very striking manner by the admirable researches of Sir Humphry Davy into the explo-

sive properties of light carburetted hydrogen, or *fire-damp*; for they show that while seven or eight parts of air to one of gas produce the greatest explosive effect, other proportions are less dangerous: in fact, a mixture of equal parts of gas and air will burn, but it will not explode. The same is the case with a mixture of two of air, or even three of air, and one of gas; whereas four of air and one of gas begin to show an explosive tendency, and this becomes more and more marked up to seven or eight of air to one of gas. His experiments also prove that one part of gas to ten, eleven, twelve, thirteen, or fourteen of air were also inflamed, but the violence of the combustion became less and less; and when the mixture consisted of fifteen parts of air to one of gas, there was no explosion at all.

These results indicate that the most easy way of destroying the inflammability of coal-gas, is the mixing of it with a large proportion of atmospheric air; and hence the necessity for good and effective ventilation wherever there is an escape of gas. We can recognize the odour of gas long before the mixture acquires explosive properties. Dr. Alfred Taylor states that the smell of gas is perceptible when it is mixed with five hundred parts of atmospheric air; and that it is very manifest when it forms one part in a hundred and fifty of air. We have, therefore, a ready means of discovering the danger; and, indeed, the offensive odour of coal-gas is one of its most valuable properties; for if it were to be deprived entirely of its odour, accidents would be far more frequent than they are at present.

As gas is lighter than atmospheric air, it is always disposed to accumulate in the upper part of the room; and here it is that ventilation will be most effective. Still, however, there is a strong diffusive power possessed by all gases, by virtue of which they rapidly comingle; and hence the necessity for a complete displacement of all the atmosphere of a room in which coal-gas has been escaping.

Dr. Taylor attaches importance to the poisonous properties of coal-gas, saying that there are reports of six deaths on record, where persons have been killed by sleeping in rooms near to which there was a leakage of gas. M. Tourdes found that an atmosphere containing one-thirtieth, or even one-fiftieth, part of coal-gas seriously affected animals. It cannot, therefore, be too strongly impressed upon the minds of those who use gas in dwelling-houses, that where a smell is perceptible, the defect should be immediately found out and remedied. When the leakage is comparatively slight it may endanger the lives of those who sleep in or near the spot; and when it has reached a higher point, it may lead to a serious accident by explosion. The effects which it produces on the human system are those of depression, headache, sickness, and general prostration of the vital powers, followed by deep coma.

Gas Ventilation.—It has been already stated that the products of gas combustion are very pernicious—that they not only cause discomfort to the feelings, and perhaps injury to the health of those who inhale them, but they are also very destructive to property; besides which, the high temperature which is produced in rooms where gas is burnt in a wasteful manner, is very objectionable. All these circumstances render it necessary that the products of combustion, as well as the heated atmosphere, should be removed as speedily as possible. In fact, it is of the greatest importance that gas should be consumed in such a manner as not to affect the atmosphere of the room at all. Several contrivances have been suggested for the purpose of effecting this.

Many years ago, when the books in the library of the Athenæum Club-house were found to have been impaired by the gas used in the building, Professor Faraday invented an apparatus which was found to remedy the evil. It consists of an ordinary bat's-wing,

or fish-tail burner, enclosed in a globe or bell-glass, closed at the top with mica; the interior of the globe communicates with a tube, which surrounds the gas-fitting, and passes away through a condensing cistern to a ventilating-shaft. The tubes are so arranged as not to be visible, and the burners are suspended in the ordinary way from a chandelier. By this contrivance the gas burns in a closed chamber, and the products of combustion are at once carried away. This plan of consuming gas is practised at the club-house before mentioned, and also at Buckingham and Windsor Palaces; but the great objection to it is the frequent breaking of the glasses, and the necessity for a ventilating shaft with a strong upward current.

The *sun-burner*, which is in use at the Philharmonic Hall at Liverpool, has already been described, and so also has the ventilating burner of Mr. Carter (see Fig. 51). Messrs. Whichcord and Rosser have also patented a contrivance for effecting the same purpose; it consists of a ventilating-bell and draught-tube placed over the burner. If the bell is lowered so as to be a little below the level of the glass chimney, and the whole surrounded by a glass globe which is open only at the top, a current of atmospheric air passes down over the tube and chimney, and thence to the flame, where it is consumed, after which it passes away through the draught-tube. By this means the air is heated before it reaches the flame, and therefore the intensity of light is augmented; besides which, the cooling influence of the air on the draught-tube and chimney prevents the heat of the gas from being communicated to the room.

Another mode of effecting ventilation, is to place a simple catch-tube, or funnel, over the gas, and thus to carry away the products of combustion into a neighbouring chimney, or to the outside of the house. The draught-tube need not be very large, and it may be hidden above the ceiling. When this plan is not available, a less perfect mode of ventilation may be adopted by boring a number of holes through the ceiling immediately over the chandelier or burner. The holes should be about half an inch in diameter, and they should communicate with the space above the ceiling. A few ventilating bricks should also be introduced into the wall, bounding the space on each side of the house, so as to carry off the warm air. The holes in the ceiling may be hidden from view by means of a perforated or open rosette.

Lastly, where gas can be burnt out of the room altogether, it is of the greatest importance that no plan of internal combustion should be adopted. Shop-windows, for example, are best lighted by means of an external jet with a reflector. On the Continent this is the plan very generally employed; and it is found to produce a much more pleasing effect, than when the burners are placed on the inside of the windows. One of the best forms of lamp for this purpose is that manufactured by Mr. Reichenbach, of the Borough Road. It is arranged so as to diffuse the light very perfectly, and it has an adjustment whereby the reflector may be placed at any angle. There is no reason why gas may not be used in a somewhat similar way for illuminating private rooms. At present we generally receive the light from the ceiling, and the combustion takes place in the atmosphere of the room; but it is quite possible to burn the gas in a closed chamber at the side of the room; say, for instance, in a recess which might be formed by removing a portion of the wall in some convenient situation, as between two windows. This recess might have a number of small gas-burners with reflectors behind them; and it might be covered in front with ground-glass, ornamented with some device. It should, of course, communicate with the external atmosphere, and be shut off from the room. By day it might be covered by a mirror; and at night the mirror might be slid to one side, so as to form a shutter for a window. Again, in some situations where

the space between the ceiling and the upper floor is very considerable, a ring of gas jets, or a sun-burner, might be introduced into a closed chamber in the ceiling, and the light might be reflected or diffused in a very agreeable manner. In short, there are many plans which might be suggested for a more perfect and wholesome mode of burning gas for illuminating purposes than that which we generally employ; and there is no doubt that if attention were sufficiently aroused to the importance of this subject, many improvements would be adopted.

Vitiating Effects of Illuminating Agents.—Although gas is generally regarded as the most injurious of all light-giving bodies, yet this is not true when we consume it in moderation; that is, when we burn it in such a manner as to obtain the same amount of light as we are accustomed to have from other agents. This will be made evident from what follows. A very little consideration will show that we have become exceedingly wasteful in the use of gas, burning it in situations where we obtain the least possible advantage from its luminous effects, and demanding such a strong glare from it, that there is a much larger consumption of the material than need be; and consequently there is a larger vitiation of the atmosphere than would occur with any other illuminating agent. Take the case of an ordinary sitting-room. With two candles on the table, at a distance of a foot from the observer, he can see well enough to read, write, or work. But suppose that gas is introduced into the room: it is placed in a chandelier four or five feet from the table, and then, according to the law of intensity, it requires twenty-five candles' worth of light to give the same amount of luminosity on the table; and so two or three gas-burners, consuming in all about ten cubic feet of gas per hour, are fitted up to do the work of two candles. It is this profusion of light and heat which has occasioned so strong a prejudice against the employment of gas, on the score of its heating and vitiating effects; but the prejudice is not well-founded. Dr. Frankland has made experiments to determine the relative amounts of carbonic acid produced by the usual illuminating agents, and he states that the following proportions of carbonic acid are produced per hour during the combustion of a sufficient quantity of each of the materials to get the light of twenty sperm candles, each burning at the rate of one hundred and twenty grains per hour:—

Tallow	10·1 cubic feet.
Wax	8·3 ,, ,,
Spermaceti	8·3 ,, ,,
Sperm oil	6·4 ,, ,,
Common London gas	5·0 ,, ,,
Manchester gas	4·0 ,, ,,
London cannel-gas	3·0 ,, ,,
Hydrocarbon Boghead gas	2·6 ,, ,,
Hydrocarbon Lesmahago gas	2·3 ,, ,,

Now, if we bear in mind that each cubic foot of carbonic acid involves the destruction of nearly five cubic feet of air, and that, according to toxicologists, a proportion of five per cent. of carbonic acid in the atmosphere is dangerous to animal life, we shall perceive that there is an enormous amount of atmospheric air vitiated and rendered irrespirable from this cause alone; but to this must likewise be added an almost equally large quantity of oxygen which is consumed by the hydrogen of these illuminating agents, and which in coal-gas amounts in many cases to nearly fifty per cent. It will be manifest, therefore, that in obtaining artificial light by any of

these means, we destroy a large quantity of atmospheric air; and hence provision should be made for an ample supply of it by means of good ventilation. This will be still more evident from what follows.

Mr. Lewis Thompson has instituted a set of experiments for the purpose of ascertaining how long a flame of a given intensity, obtained from different illuminating agents, will burn in a given bulk of atmospheric air. In all cases the value of the light emitted was the same—namely, that of thirteen standard sperm candles, each of one hundred and twenty grains' consumption per hour; and a distinct experiment was made with each agent. The times that elapsed before the flames were extinguished were as follow:—

Rape or colza oil	71 minutes.
Olive oil	72 ,,
Russian tallow	75 ,,
Town tallow	76 ,,
Sperm oil	76 ,,
Stearic acid	77 ,,
Wax candles	79 ,,
Spermaceti candles	83 ,,
Common coal-gas	98 ,,
Cannel coal-gas	152 ,,

These times are inversely as the salubrity of the illuminating agent; and hence it follows that common rape oil is the most destructive of the atmosphere, and rich cannel-gas the least.

The same is true of the heating effects of these bodies. Already we have alluded to this fact; but as it has been made the subject of special experiment by Mr. Lewis Thompson, we will again refer to it. He says that when the following materials are burnt for an hour, in such quantity as to give the light of one sperm candle of one hundred and twenty grains' consumption, they raised the following amounts of water from the temperature of 60° to 212° Fah.:—

Cannel-gas	raised	4074	grains	of water	152°
Common gas	,,	6840	,,	,,	,,
Sperm candle	,,	7305	,,	,,	,,
Tallow candle	,,	7534	,,	,,	,,
Colza oil	,,	7870	,,	,,	,,

"The impossibility of maintaining one uniform rate of consumption in the case of the candle and oil, detracts slightly from the value of the results; but the indications are too decisive to permit the general conclusion to be doubted—that, light for light, the inconvenience arising from heat is much less with gas than with any of the ordinary agents employed to give light; and in the case of cannel-gas the advantage is very great."

ILLUMINATING AGENTS WHICH DO NOT VITIATE THE ATMOSPHERE.

Of these there are two which are especially deserving of notice: these are the oxy-hydrogen, or Drummond light, and the electric-light.

The Oxyhydrogen Light.—This was first introduced to public notice by Lieut. Drummond. It consists of a jet of oxygen and hydrogen gases, or of alcohol and oxygen,

burning so as to ignite a piece of lime or magnesia; and the high temperature which is thus produced renders the earthy body so incandescent as to be intensely luminous.

The apparatus which is employed for the production of this light has, at various times, undergone considerable alteration and improvement. Originally the mixed gases, consisting of two parts, by measure, of hydrogen and one of oxygen, were condensed, by means of a syringe worked at great pressure, into a square metal box, from which there issued a long jet, of very small bore; this jet passed through a thick oak partition, in order that the operators might be protected from the danger which was incidental to the bursting of the metal-box from explosion. This was the form of apparatus originally contrived by Clarke and Newman. After this the safety-jets of Gurney, Hemming, and others, were adopted; and at the present time it is customary to burn the mixed gases by means of the latter, or else to deliver the gases separately into a double jet or nozzle, where they mix immediately before they are consumed. Both of these plans are very manageable, though the latter is thought to be less open to the risk of explosion than the former.

The hydrogen gas is obtained by acting on zinc with dilute sulphuric acid (one of acid to ten or twelve of water); and the oxygen, by heating a pulverulent mixture of four parts of chlorate of potash and one of peroxide of manganese in a glass retort. In each case the gas is to be collected in a gasometer, or else in bladders fixed to receivers over a pneumatic trough. Mr. Watson has obtained a patent for procuring the gases already mixed in proper portions by the decomposition of water by galvanic agency; but the process is an expensive one.

When the mixed gases are burnt, the flame is projected upon a small cylinder of lime or magnesia, which is from time to time turned round, so as to expose a fresh surface to the action of the flame.

Another mode of obtaining this light is to throw a jet of oxygen into a flame of spirit of wine or ether, or to mix the oxygen with coal-gas instead of with hydrogen.

The light which is obtained by either of these plans is very intense. When concentrated by means of a concave mirror, it is distinctly visible at a distance of sixty-five miles; and it is calculated that when it is compared with the light of a wax candle, the mixture of oxygen and coal-gas is equal to twenty-nine of such candles, that of alcohol and oxygen to sixty-nine, that of ether and oxygen to seventy-six, and that of hydrogen and oxygen to a hundred and fifty-three. In consequence of the great intensity of the oxyhydrogen light, it is generally employed for the phantasmagoria, the dissolving views, the solar microscope, and for theatrical illuminations, and experiments in optics; besides which, it has been recommended for light-houses and signal-lights. The light differs from all others which have been described, in the circumstance of its being exceedingly white, and therefore well suited for the display of bright and delicate colours. With this light the various shades and tints of a picture or dress are as plainly discernible as they are by the diffused light of day.

The Electric Light.—Within the last few years public expectation has been raised to a great height by the announcement that voltaic electricity might be made the means of producing a very pure and intense light; and several patents have been taken out for the purpose of accomplishing this. Indeed, many exhibitions of the light have been made at several public institutions, and also in the open air, by which the sanguine hopes of its originators have been apparently increased. Of late, however, little has been heard of the subject beyond the few remarks which occasionally fall from men of science in their discourse upon it.

The idea of employing electricity for this purpose is not novel; for the power of the voltaic light was thoroughly investigated in the time of Sir Humphry Davy; but the difficulties which electricians had then to contend with in the inconstancy of the galvanic battery, offered an insurmountable barrier to its use. A part of this difficulty was overcome by the late Professor Daniell, who was the first to contrive a constant battery. Since then the voltaic arrangements, by which a current of electricity of great power may be sustained for any length of time, have been improved by Mr. Smee, Professor Grove, M. Bunsen, and the Rev. Professor Callen of Maynooth; so that at the present time there are abundant facilities for producing the light.

The first patent which was taken out for the use of electricity for illuminating purposes, was that of Mr. Staite in November 1846. In July 1848, he obtained another patent for an improved form of battery. This he called the *perfluent* battery, in contradistinction to the *percolating*, which was already in use. It was thus named on account of the arrangement which he adopted for keeping up a supply of acid. The troughs, or cells of the battery, communicated with each other by means of elastic syphons or cross tubes, and the acid was made to flow from cell to cell throughout the entire length of the series, so that when it arrived at the last cell it was completely exhausted of its exciting power, and saturated with zinc. It was thought that such an arrangement would be the means of economizing power and material; but it happens to be the very worst that could possibly have been contrived for such a purpose. The electrician knows that if he requires the greatest power from his battery, each of the cells must be acting alike and to their fullest extent; for it is the condition of electricity to multiply itself, not after the ratio of the most powerful cell, but after that of the weakest. If, therefore, we have in the arrangement a number of cells working differently, as is the case in the perfluent battery, the activity of the one set of cells will be of no avail in raising the inactivity of the other; for the least powerful cell governs all the others, and reduces them to its own standard. It follows, therefore, that the last cells in Staite's arrangement must act as clogs on the first; for, as they are almost without action, they must reduce the power of the first cells to little or nothing. Another alteration, proposed by Mr. Staite, was that a liquid amalgamation of zinc and mercury should be used in bags, or porous cells, in lieu of the ordinary form of amalgamated zinc. He also suggested the use of a solid amalgam consisting of 5 of zinc and 1 of mercury. He likewise proposed that lead should be employed instead of zinc, in order that valuable products might be obtained. All these suggestions, however, are of no value; for they are contrary to the principles on which a good galvanic battery ought to be constructed.

In July 1848, the Chevalier Alexandre Edouard Lemolt also took out a patent for improvements in the batteries and apparatus used in obtaining the electric-light. His improvements in the battery were but modifications of those long since adopted by Professor Bunsen. He employed plates of carbon, which were either cut out of the hard coke which lines the interior of gas-retorts, or else formed by powdering the coke, mixing it with a little coal-tar, then pressing it into a mould and baking it at a low red heat. Since then—namely, in the month of February 1849—Mr. Charles Thomas Pearce obtained another patent for improvements of a like description. His battery was a perfluent one, and it differed from Staite's in the circumstance that the flow took place separately in each cell, and not from cell to cell; so that the amount of power generated in each cell was the same, and his porous diaphragms were made of sycamore wood, soaked in dilute acid. Another of his claims was the use of alkaline salts in solu-

tion, which did away with the necessity for amalgamating the zinc. Lastly, another patent has since this been obtained by Messrs. Staite and Petrie, wherein they recommend a modification of their former arrangement, so as to keep the liquids in all the cells of the same degree of strength. Each of these patentees has likewise secured to himself the use of certain contrivances, whereby the charcoal-points which emit the light shall be removed and kept at a proper distance from each other. These, in fact, constitute the real claims to consideration; for the batteries which they have invented are not worthy of the least attention.

Batteries used in obtaining the Electric Light.—(*a.*) *Daniell's Battery*, which consists of a jar containing a cylinder of sheet copper, and a saturated solution of its sulphate; within this there is placed a porous cell (composed of brown paper, unglazed earthenware, or bladder), which holds a cylinder of sheet zinc, and a solution of common salt. These are arranged so as to obtain both quantity and intensity of electricity.

(*b.*) *Grove's Battery* is constructed in a very different manner. The outer cell is of an oblong form, and it may be made of glass, earthenware, or gutta-percha. It contains a piece of sheet zinc bent into the form of the letter U, one leg being a little longer than the other. The zinc is amalgamated according to Mr. Smee's plan, by dipping it into dilute sulphuric acid, and then covering it with quicksilver. Within the bend of the zinc there is placed a porous oblong cell of unglazed earthenware, and within this a sheet of platinum. The battery is set in action by pouring dilute sulphuric acid (in the proportion of one acid to seven water) into the zinc compartment, and strong nitric acid into the platinum cell. As before, the battery is to be arranged for quantity as well as intensity.

(*c.*) *Bunsen's Battery*, as well as that modification of it proposed by M. Lemolt, is truly a Grove's battery, with a piece of charcoal instead of the sheet of platinum.

(*d.*) *The Maynooth Battery*, which was contrived by the Rev. Professor Callen of Maynooth, is also a modification of Grove's principle; for a plate of cast-iron is used instead of platinum, and the cast-iron cell is charged with a mixture of two parts of strong sulphuric acid, one and a half of nitric acid, and the same of water; and it is better to excite the zinc with a strong solution of muriate of ammonia instead of with dilute sulphuric acid, for this does away with the necessity for amalgamating the zinc.

Professor Grove says that the result of his experience is, that the nitric acid battery, in one or other of the preceding forms, is the only one hitherto invented which offers anything like a practical means of applying this power to illuminating purposes; and the best arrangement that can be adopted for obtaining the greatest amount of power is to use about forty or sixty cells, arranged in two series of twenty or thirty each. By this means we have the quantity of two cells, and the intensity of twenty or thirty. If we go beyond this in the intensity arrangement, the fluids in the cells begin to boil and quickly to evaporate. This is objectionable; for it not only renders the atmosphere of the room irrespirable, but it frequently brings the action of the battery to a stand-still. The source of power in all cases is the chemical action which takes place in the cells.

Mode of Obtaining the Light.—The wires which convey the electricity from each of the series must be connected, so that the two positive poles are brought together and the two negatives. The wires should be of large size, so as to conduct the electricity with ease; and they should be covered with gutta-percha, so as to insulate them. If this precaution is not taken they may touch each other, and so cut off the current; or they may become unmanageably hot; or they may communicate a shock to the operator. It

is usual to have the galvanic batteries in any convenient place at a distance from the experimenter, and to convey the electricity, by means of the insulated wires, to the point where it is wanted. Light may be obtained from the battery in two ways: either by bringing the poles into contact with a yard or so of platinum or iridium wire, wound into the form of a spiral; or by terminating them with cylinders of charcoal, and then bringing them into contact. In each case the light is produced by the ignition of the conducting medium. Platinum or iridium is not so well suited for the purpose as charcoal, because, in the first place, the light is never so vivid, and, in the second place, the metal is very likely to fuse, and put a stop to the experiment. When charcoal is employed, it is found that the greatest intensity of light is produced by drawing the points apart to the extent of from a quarter to half an inch; and then there is a stream of finely-powdered charcoal, in a most intensely ignited state, projected from one pole to the other, forming an arc of flame. If the charcoal-points are too close together, we do not obtain the maximum effect; and if they are too far apart, the arc is broken, and the light extinguished. This it is which constitutes the difficulty in keeping up the electric-light, and which gives to the flame its unsteady, flickering character. Consequently, all the contrivances which have been adopted for overcoming this have been made the bases of the several patents to which we have alluded. These we shall now proceed to describe.

Apparatus for sustaining the Electric Light.—The first of Mr. Staite's patents was for a contrivance or method for maintaining the charcoal-points at an uniform distance. One of these is represented in Fig. 57: *a* and *b* are the charcoal-points; they slide easily in a brass tube which holds them, and their free ends rest upon a solid cylinder of plaster of Paris *c*. At the opposite ends they are pressed upon by a spiral spring, which is contained within the brass tube; and by which means they are always forced down very firmly on the plaster of Paris cylinder. There is an adjusting screw at *d* for regulating the distance of the points, and the arms *f g* convey the current. To set it in action, the two charcoal-points are made to touch by means of the adjusting screw *d*, and then they are separated to the required distance, so as to get the maximum amount of light. As the points burn away, the springs keep up a fresh supply by forcing them down on the plaster of Paris cylinder, and maintaining them at their proper distance. It was at first thought that this arrangement would meet all the difficulties of the case; but it was soon found that there were irregularities in the action of the battery, as well as a projection of the charcoal from one pole to the other, which demanded a constant motion of the points; and, therefore, a few months afterwards the patentee adopted

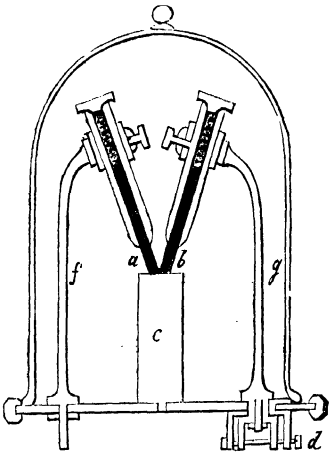

Fig. 57.

another invention, whereby the points were adjusted by the aid of an electro-magnet. A third patent, with still further improvements in this respect, was obtained in the course of the same year. In this last patent there are three distinct kinds of apparatus described for the management of the electric-light—namely, one for obtaining a regularly intermitting light, another for procuring a constant and uniform light, and a third for developing a constant light by the ignition of a metallic wire.

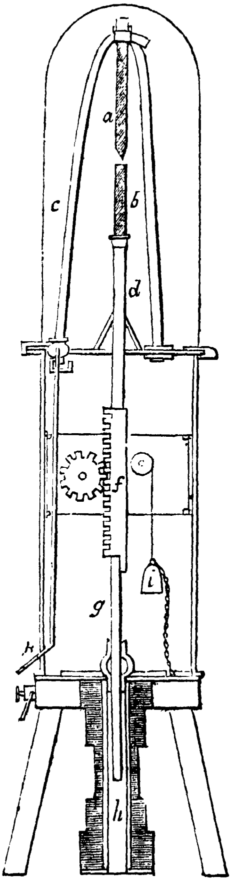

Fig. 58.

The apparatus for producing the first effect is represented in Fig. 58: *a b* are the two charcoal-points; one of them is fixed to the conductor *c*, and the other to the moveable rod *d*. The lower part of *d* is fixed to a rack *f*, and this to an iron rod *g*, which moves freely up and down in a tube *h*, that is surrounded by a coil of wire in the form of a helix: a weight *i* is attached to the rod *f g* by means of a string, which passes over a pulley. The object of this is to counterbalance the weight of the rod, rack, and charcoal-holder; and there is a small piece of chain also attached to the weight, so that the balance may be equalized as the rod is pulled down. The action of the apparatus is as follows:—The conductor *k* and the wire of the helix around *h* are brought into connection with the galvanic battery, and the circuit is closed by bringing the two charcoal-points into contact. At this moment the iron rod *g* is rendered magnetic, and is drawn down into the hollow tube within the helix. By this means the charcoal-points are separated, and a most intense light is produced; but soon the separation takes place too far, and then the circuit is broken and the light extinguished. The iron bar now loses its magnetism, and the weight draws it up again, so as to bring the charcoal-points once more into contact, when the same phenomenon is repeated. It is obvious that by this contrivance a succession of flashes at regular intervals is produced, and the weight may be so regulated as to maintain any period for the duration of the light and its intermission.

The apparatus for producing a constant and uniform light is shown in Fig. 59. The charcoal-points A B are attached as before—one to a fixed conductor C, and the other to a moveable conductor D; the latter is moved by a rack F F which works into a pinion, and this turns on a spindle with fixed supports. A barrel is attached to the pinion, and over this there passes a string to which the weight G is fastened: by this means the rod and rack D F are counterpoised. To the spindle there is fixed a cogged wheel H and a lever I; the latter carries a double paul, which locks into the cogs of the wheel in either direction. A long horizontal lever K passes over

the paul, and moves on the fulcrum L; while it supports at one end a rod M, which is fixed to an iron bar N, and at the other a moveable counterpoise O. The iron bar travels freely up and down in the coil P.

The paul and its lever I are kept in a state of slow vibration from side to side by means of a crank R, which works in a fork at the end of the lever I. This crank is made to revolve by an ordinary train of wheel-work, furnished with an escapement or fly-wheel, and driven by spring-power or by weights. The object of this movement is to elevate or depress the rack F by turning the wheel H.

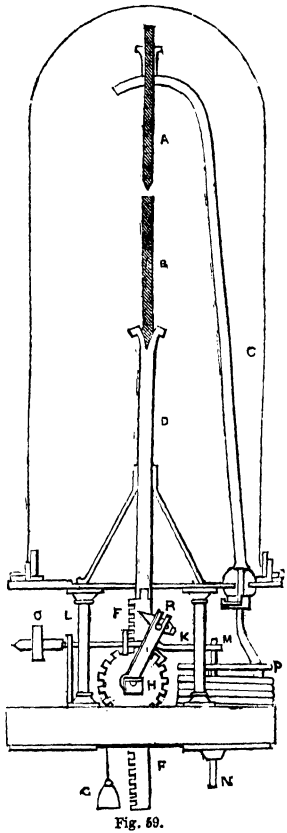

Fig. 59.

The mode of action of the apparatus is as follows:—The negative pole of the battery is brought into cantact with the rack and rod D, F, and the positive pole with the coil P, and thence with the upper charcoal support C. Immediately the points touch, and the circuit is completed, the coil raises the iron rod N. This acts on the lever K, and causes the lower charcoal-point to descend and separate from the upper one. Directly the separation has taken place to the maximum extent, there is a contrivance (not shown in the drawing) which arrests the movement of the rack, and so keeps the electrodes stationary. Before the apparatus is set to work, the proper distance for the charcoal-points is adjusted by means of the counterpoise O, which screws backwards or forwards on the short arm of the lever K, and thus regulates the movement of the rod M, N. If the light should go out, and the circuit be broken, the rod N immediately falls, pulling down with it the long end of the lever K. This presses upon one arm of the paul and gives motion to the wheel H, whereby the rack is elevated and the charcoal-points again brought into contact.

M. Lemolt's apparatus for adjusting the charcoal electrodes is somewhat different from the last. In the first place, the electrodes are not cylindrical, but are in the form of circular discs, *a*, *b*, Fig. 60; and they revolve freely on two arms, which move separately on one common axis *c*. This axis also carries a pinion, the square cogs of which are in communication below with the driving-wheel *d*, and above with another pinion *f*, the inner cogs of which are in gear with a large wheel *g*. Over the drum of the pinion at *c*, there passes two endless pulleys, which give motion to the charcoal discs *a*, *b*. In order that the discs may be at a proper distance for the production of a good light, there are two adjusting stops *h h*, fixed to the arms on

which the discs rotate. These stops are brought into close contact with two cams, which are situated in the periphery of the wheel *g*; and as this wheel rotates, the charcoal discs are brought closer and closer together, so as to compensate for the wear of the electrodes. There is a spiral spring at *i* to keep the arms and their stops tight against the cams. The apparatus is thus set in motion —the terminal wires of the battery are brought into connection with the charcoal discs by means of the conductors *k*, *l*. The driving wheel *d* is then set in motion by clock-work within the case of the instrument, and its motion is communicated to the other wheels and also to the charcoal discs. The discs are then brought together so as to complete the circuit, and the stops are adjusted in the cams, so as to produce the necessary arc of flame. By the revolution of the discs, new surfaces are constantly presented to each other, and the old or worn edges are cleaned down by the sides of the stirrups in which they revolve.

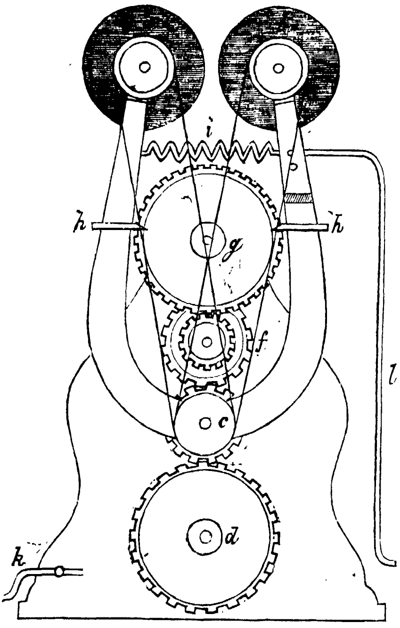

Fig. 60.

In Mr. Pearce's arrangement, there is a prismatic or cylindrical bar-electrode in contact with one, two, or three of a discoid form. These are moved by clock-work; and it is so managed, that while the first advances or rises through its sheath, the others revolve at a proper distance from it, and the edges are kept clean by means of iridium cutters. The charcoal bar is also held by the iridium conductors, which grasp it close to the ignited point. The advantage of this mode of mounting the electrodes is, that if from any cause, such as unequal waste of carbon, or irregularity of surface, the light should be extinguished at one point, the others remain burning, until by the further revolution of the disc, or the advance of the bar, the electrodes are again brought into contact, and the light restored. Besides which, in presenting two or three centres of light, so merged as to appear as one in a reflector, there is greater brilliancy and greater steadiness of flame.

Another apparatus has been patented by Mr. Pearce, which does away with the necessity of clock-work altogether. It consists of two bar-electrodes, which are approximated by means of springs or weights and pulleys; and the necessary distance is preserved by the intervention of slips of non-conducting charcoal. He has also contrived a plan for relighting the electrodes in case the arc of flame is blown out. This he effects by aid of a wedge-shaped piece of charcoal, which falls down between the electrodes directly the light is extinguished, and thus re-establishes the contact. The

charcoal is fixed at one end of a lever, and to the other end there is a soft iron armature: this is placed opposite to a soft iron magnet, enclosed in a coil which carries the current. While the electricity is passing, the electro-magnet draws the armature to it, and so keeps the wedge-shaped piece away from the electrodes; but directly contact is broken, the armature retires, and the wedge-shaped piece falls down between the poles and re-establishes the arc.

Mr. Staite has patented a plan for obtaining a constant and uniform light by the ignition of a loop of platinum or iridium wire, enclosed in a glass globe from which the air has been exhausted. But there is no novelty whatever in this contrivance; and, consequently, it is undeserving of further notice.

Some little attention is necessary to the quality of the electrodes in order to get the best effect. *Common charcoal* is unsuited for the purpose, because of its being in most cases a non-conductor of electricity; the *charcoal of porous wood* is also objectionable, from the circumstance of its burning away very rapidly: therefore it is that electricians make choice of the densest varieties of carbon. One of these is the *charcoal from box-wood*, which is obtained by cutting the wood into pieces of nearly the required form, then putting into a crucible, filling up with fine sand, so as to secure the exclusion of atmospheric air, and exposing for two or three hours to a bright red or white heat. The crucible is to be well covered and allowed to cool before the charcoal is taken out.

Hard coke has been employed with considerable advantage by many persons. The objection to it is that it frequently scintillates, from the large quantity of iron which is contained in it. This difficulty may be overcome by powdering the coke, then stirring it about with a magnet so as to attract the iron, or else digesting it in nitro-muriatic acid and washing very well before drying. The powdered coke is then to be moistened with a little syrup or coal-tar, and rammed into a cylindrical mould: the bar which is thus made must be ignited in a crucible covered with sand, in the same way as that already described for the preparation of boxwood charcoal. These cylinders will be found exceedingly hard, and they give a light which is superior in whiteness and intensity to that from any other kind of charcoal. If the electrodes are soaked in a strong solution of common salt, and then dried, they give a still more brilliant effect; and by using a salt of copper, chloride of strontium, &c., we obtain green, red, and other coloured flames.

Again, it has been noticed that the intensity of the light is increased by removing the atmospheric air from the vessel containing the electrodes, and effecting contact in a rarefied atmosphere, or in a vacuum. The *effects* which are produced in this manner are very remarkable; for the purity and intensity of the light are greater than those from any other source. In the first place we find that it simulates the light of the sun, in the circumstance of its affording a means of distinguishing the most delicate tints of colour: blues, yellows, and whites, which are not to be seen in a pure state by ordinary artificial light, are recognizable by this mode of illumination as if they were seen by day. Again, when the light is decomposed by a prism, we obtain a spectrum which is similar to that afforded by the rays of the sun.

The intensity of the light has been variously estimated. That which was exhibited by Mr. Staite on the 30th of May, 1849, from the summit of one of the towers of the Hungerford Suspension Bridge, was said by him to be equal to 750 wax candles. Professor Grove, in experimenting with a battery of thirty cells, the platinum being four inches by two, obtained a light which equalled that of 1444 wax candles; and Dr. Letheby states, that in some experiments which were made by Mr. Hearder of

Plymouth, in the month of April, 1849, with a Maynooth battery of eighty cells, each four inches square, arranged in two sets of forty each, the light, when concentrated by a parabolic mirror, and sent over the country for a space of 5490 yards, gave a light equal to that of a candle at thirty feet distance; so that the intensity of the focussed light was equal to that of 301,401 candles. It is probable that Mr. Grove's estimate is nearest to the truth, as great pains were taken in his investigations to arrive at correct results.

It is very natural that a light of so great brilliancy should command a large share of public attention, and should likewise be made the subject of frequent experiment. Hence it is that Mr. Staite and others have often exhibited it in London and elsewhere. When it was shown from the top of the Hungerford Suspension Bridge, the light was sufficiently intense to illuminate the water-frontage of Somerset House; and when it was cast to the opposite side of the river, it lighted up all the buildings on the Surrey shore. Exhibitions of it have also been made at the Hanover Square Rooms, from the top of the Duke of York's Column, and from the portico of the National Gallery; but the most marvellous illustration of its power was afforded by Mr. Hearder of Plymouth, who placed the light at the top of the Devonport Column, and first experimented with it at Trematon Castle, which is distant about 18,266 feet; and then at Bovisand, which is 16,470 feet from the column. At the former place the light was sufficiently strong to mark the time on the seconds-hand of a small watch, and the walks of the castle were distinctly visible at a distance of half a mile; besides which, the ivy-leaves over the gateway of the building were plainly seen when the observer was sixty feet away from them. Its intensity, says Mr. Tucker, who reported upon it, was magnificently brilliant. At Bovisand the light was sufficiently strong to cast a shadow of objects on a yellow wall, and it was thought to be about equal in intensity to that of the full moon when at its meridian in a calm clear night. At that distance, without the reflector, it looked like the planet Venus when seen through a telescope.

The following are the accounts given of these effects as seen at Bovisand and Trematon by Messrs. Walker and Tucker, the two gentlemen who were deputed by Mr. Hearder to make the necessary observations. The accounts are extracted from the *Plymouth Herald* for April 21st and May 5th, 1849. Mr. Walker writes thus:—

"With regard to our observations at Bovisand. About half-past eight o'clock we saw flashes and glimmerings of a bluish light from the column at Devonport, which, to all but myself, were unsatisfactory. The people thought that something had gone wrong. The light was then, in all probability, on the Trematon side of the column, the column being directly between us and the light itself. After waiting for some time, we finally saw the electric-light outshining all the other visible lights, and we sent up a rocket or two to indicate our satisfaction. Our personal shadows were projected upon a boat-house door (painted yellow and itself illuminated) by the electric-light, and pronounced equal to that of the full moon when on the meridian in a calm clear night.

"A candle (six to a pound) projected a similar shadow upon the same door, illuminated in the same way, at a distance of 30 feet from the person whose shadow was thrown upon the door. That is to say, the shadow projected by the electric-light at a distance of 5,490 yards, was just equal to the shadow projected by a single candle at a distance of 10 yards. Consequently, their illuminating powers were as 10 (squared) : 5490 (squared), or as 1 : 301,401. This comparison is rather a 'stunning' one! I am of opinion that the electric-light possesses a space-penetrating power

infinitely superior to any light we can obtain by combustion, since it is free from all carbonaceous or solid particles!

The Breakwater light may probably be equal to 24 Argand lamps, each equal to half a dozen candles; yet *this* light projected a shadow *only* slightly visible at a distance of 500 yards, while the electric-light projected shadows, at lucid intervals, strong enough for children to make *rabbits* with their fingers upon a wall more than 500 yards distant from the light itself; that is to say, ten times farther than from a lighthouse that could only throw a shadow 'faintly visible.' The electric-light, as seen in the open air, may be compared (as far as colour is concerned) to that of the planet Venus when seen through a telescope, or to the light of a glow-worm, or to those brilliant flashes of light we sometimes see within the Tropics from the waves when surcharged with phosphorescent matter."

And Mr. Tucker's account is as follows:—"Sir,—A variety of occupations have prevented my sooner informing you of the effect produced here by the electric-light, on the evening of the 12th inst. You are aware that this castle is 18,266 feet distant to the N.N.W. from the Column at Devonport. The reflector which you used was one from which the rays diverge. The evening was very favourable, but little breeze (E.N.E.) was stirring, yet sufficient to blow off the smoke from the town. The atmosphere was so clear that the Devonport lamps were very distinctly visible, and the stars which appeared shone very brightly; but they were few, and the moon had not yet arisen. The instant the light shone, the lamps of Devonport were all-but totally eclipsed; as it fell upon a sail spread over the walls of the keep, we immediately perceived that a shadow was cast by the fingers of a hand upon the sail, by a twig of ivy, and by the stem of an ivy-leaf. We could clearly see what o'clock it was by our watches. I ascertained the light to be polarized, and the whole effect was very striking, for the light upon the column was exquisitely beautiful—its brightness was magnificently brilliant. The interposition of the red shade then informed us that the light would be changed. When that change, whatever it were, was made, the light sensibly increased; we then could see the time by the seconds-hand of a small watch; the usual hand-writing was read; and the ivy-leaves on the gateway tower were seen at the distance of 90 feet. Persons more than half a mile behind the keep could plainly see the walks around it; and we all were very much pleased by the striking effect produced by your turning the reflector upwards towards the clouds, which we clearly saw, the light then having the appearance of the tail of a huge comet, the reflector being the nucleus. I think I may state that the breadth of the intensity of the light was at least three-quarters of a mile; and I believe that persons standing on the Brick-field (close to Devonport) saw the light reflected to them from a looking-glass which was suspended from the keep."

If the electric-light is exhibited in a room where there are gas or other lights, the intensity of the former is so great that it actually produces shadows of the flames of the others. At the Polytechnic Institution the electric-light is used for the purpose of illustrating the optical effects of refraction and reflection in a stream of water—as seen in Dubosque's fountain; and at the Panopticon, the spray from the large *jet d'eau* is illuminated by several electric-lights that were placed at the very top of the dome. The chromatic effects are produced by means of coloured glass, which is rapidly shifted before the light.

As to the economy of the light, little can be said. Professor Grove stated, that in his experiments with the battery which gave the light of 1444 wax candles, the cost

was at the rate of about 3*s.* or 3*s.* 6*d.* per hour; and Mr. Ward, who has devoted attention to this part of the subject, states that to obtain a given light with 100 pairs of Smee, 55 of Daniell, or 34 of Grove, each cell consuming 60 grains of zinc per hour, the cost would be about 6*d.*, 7½*d.*, or 8*d.* per hour respectively. But we apprehend that this does not include the original cost of the battery, or the charge for attendance. At the Royal Opera House, where the light was exhibited for several nights in a new ballet, it cost the manager £2 per night, although the exhibition was not of long duration, and was under the superintendence of Mr. Staite himself. In this case a Maynooth battery of seventy-five cells was employed.

This clearly indicates that the light can never be economically employed as an ordinary illuminating agent: indeed, it is manifest that as the source of power is really the same as that of other artificial lights,—namely, the oxydation of a combustible body,—it resolves itself into this, whether it is cheaper to burn gas, oil, or tallow, by means of atmospheric oxygen, or to consume zinc by the aid of water and very expensive acids. Of course some allowance must be made for the value of the products in the latter case; but then, as a set-off to this, we have to consider the expense of constructing the batteries, and of attending to them. It will, however, be freely admitted that, although it is not an economical light for ordinary purposes, it may be advantageously employed whenever a vast amount of illuminating power is required, and there are facilities for charging the batteries. It might be employed, for example, in light-houses, perhaps also in mines, in theatres, and for public exhibitions of various kinds. It has been stated that the electric-light has been used to illuminate the works of the Napoleon Docks in Paris, where the men are employed night and day in their work. The light has been employed there for four months at a cost of thirty-six francs per night: and as it served for the use of 800 men, the cost was exactly four and a half centimes, or less than a half-penny, per man. This does not look like a very expensive mode of illumination; and it is very probable that it may be resorted to in such cases as this with considerable advantage. Again, it is not altogether impracticable to have an electric-light in some convenient part of a mine, and, by the aid of reflectors, to throw the light along the different galleries and into the workings. By this means all danger from explosion in those localities where the fire-damp abounds would be completely obviated.

The Steel Mill of the Miner is the last form of apparatus for the production of artificial light to which we shall allude. Before the introduction of the Davy-lamp into the coal-mines of this country, a rude instrument was employed by the miner for the generation of light in those localities where the fire-damp rendered the atmosphere unusually dangerous. It consisted of a small steel wheel, which was made to revolve very fast by means of a small pinion that was turned by hand; and while the wheel was revolving, a piece of flint was held against it, so as to emit a brilliant shower of sparks. These gave out sufficient light for the miner to work by. It was thought that the heat from this apparatus was less dangerous than that from a candle, but Dr. Pereira succeeded in firing explosive gas with it, and thus demonstrated to the Parliamentary Committee that it was just as dangerous in a mine as a candle. At the present time the instrument is quite out of use.*

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TO

CHEMISTRY OF ARTIFICIAL LIGHT.